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NOTICE

OF

THE FOURTH PART OF

THE AIDE-MÉMOIRE.

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offering to the Subscribers the Fourth Part of the 'Aide-Mémoire to the ilitary Sciences,' which completes the Second Volume of the Work, the ditors have again to express their regret that the publication has been unavoidably layed.

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January 21, 1850.

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METEOROLOGY.—The science of Meteorology embraces the study of the atmosphere and of all atmospheric phenomena: it is therefore most important, as on such phenomena depends essentially the fitness of the various portions of the earth's surface for the production of distinct vegetable and other substances, and for the support of animal life. The local peculiarities of climate which necessarily involve the varieties of temperature, barometric pressure, direction of prevailing winds and currents, periods of the fall of rain and quantities falling, are full of interest; and it is most desirable to collect the data or the statistics of climate in a detailed manner, as the Colonist will be thus enabled to judge, even before he has learned by long and perhaps unfortunate experience, how he may best apply his labour and his capital. Although intimately connected with each other, they form separate subjects for investigation, and require to be classed under different heads. Meteorology is a branch of Natural Science which British Military Officers have it in their power greatly to advance, from the circumstance of their serving in all climates. Until recently, it has been studied in much too confined a sphere. The study of the Winds, for example, like the study of Magnetism, requires that observations should be made at distant points, and be combined. Having this object in view, Lord Glenelg addressed a circular dispatch to the Governors of the British Colonies, suggesting that harbour-masters, lighthouse-keepers, and other competent public officers, should be required to keep journals of the weather, and to enter all meteorological observations considered worthy of particular notice.

In the same manner, the Court of Directors of the East India Company sent instructions to the Governor-General of India for this object.

The local journals in the colonies generally afford an opportunity of publishing, and thus preserving, observations of this nature; and every Military Officer who contributes records of this kind will be aiding in the study of Meteorology. These newspapers are filed at Lloyd's and elsewhere in London.

It is made the duty of Officers of the Medical Department serving abroad, to keep registers of the temperature of the weather; but from these observations not being published, their value is in a great degree lost: they should, however, be examined and copied.* W. R.

MINING, MILITARY.

PART I.—INTRODUCTORY REMARKS.†

In the 'Attack and Defence of Fortresses,' in this work, the subject Military Mines was very briefly alluded to. This branch of Fortification is, however, to the Military Engineer of paramount importance.

By a study of the 'Attack of Fortresses' it will have been seen how irresistible is its march; that the means of destruction at the disposal of the besieger, and the mode of application, render the reduction of a fortress a matter of calculation. The advantages of position, number, and material, are all on the side of the besieger. But so soon as the latter is compelled to engage in subterranean warfare, these advantages cease, or rather are transferred to the besieged. It is a very remarkable change. The French authors, Gumpertz and Lebrun, speaking of the difficulties

* For the instruments, and mode of observing, see 'Anemometer,'—'Barometer,'—'Electricity,'—'Observatory, Magnetic,'—'Rain,'—'Thermometer,'—'Wind.'—*Editors.*

† By Captain Williams, R.E.

which a besieger would experience should he attempt to carry on his approaches on a glacis defended by countermines, without in the first instance destroying them, say—

"The loss of a great number of men, and the discouragement of the whole besieging force, perhaps even their defection, would inevitably follow such a resolution. When, therefore, the front of attack is countermined, the besieger must call the miners of his army to his aid. This corps,—stimulated by the importance of the services they are called upon to perform,—proud that the progress of the attack is committed to their charge,—convinced that, although their operations are concealed from the eyes of their comrades, yet their daring deeds are not the less appreciated by them,—actuated by all these motives, penetrate below the surface of the earth, armed with thunder, to seek their enemy, to struggle with him in darkness, and finally to triumph over him;—their victory being incontestably the fruit of true courage,—of skill united to valour." And still further—

"The miners of the besieged have, also, an equal claim to glory: although finally compelled to yield the victory to their opponents, it is an animating spectacle for the besieged to witness, that, by their art, the hitherto imperious march of the attack is for a time averted: so soon as it is known to the besieger that the ground over which his attack must pass is mined, then his operations become, as it were, paralyzed. The mine produces an effect in the ranks of the besieger far greater than the fire from the ramparts. The imagination exaggerates, the danger ever appearing more formidable as it is mysterious and obscure. It is in vain the bravest of the besiegers attempt to push on the attack and overcome at all price the obstacle which impedes their advance. Yet a handful of men, by a slow, dangerous, and most difficult process, conquer where numbers and courage succumb,—a striking example of the superiority of industry and skill over force; and now a struggle is commenced and carried on amidst silence and darkness. The besieged, who cannot avail himself of such large charges as are fired by the besieger, still retains on his side all the advantages of that science which foresees, observes, calculates, and regulates every thing. His attentive ear is directed to all the points by which the besieger can advance. If the latter is heard, he is lost: a volcano whose existence he suspected, but whose destructive effects he could not escape, shatters his galleries, and buries him amidst its ruins; and yet no outward sign betrays to his companions the misfortune which has befallen him. The besieger then is satisfied if he can manifest himself by any effort whatever, and amassing hurriedly a quantity of powder, explodes it in the hope of narrowing the circle of operation of the mine of the besieged, while he establishes a lodgement on the edge of the crater he has produced. But the besieged does not leave this newly acquired position long undisturbed, and by a mine which can be fired with sure and certain effect, overthrows his gabion and destroys the lodgement. Such is the débût of a subterranean warfare: its continuation and its close are but a repetition of the same process. On the side of the besieger there are precaution and perseverance; on that of the besieged, care and activity; in both, patience and courage. The last scene in the combat shews the besieged repulsed but not conquered; while he may fairly proclaim, that for the continuation of the struggle it is not courage that is wanted, but arms."

There can be no doubt, however, that all Engineers who wish to restore the balance between the attack and defence, should direct their attention to subterranean defensive operations; for by a successful application of these, may follow either the raising of a siege or a very considerable prolongation of its duration.

Military mines as a system have, however, hitherto played a secondary part in the operations of war. The only record of their extensive employment is to be found in the siege of Candia by the Turks, in 1669, and in that of Schweidnitz, in 1759, by

Frederick the Great. Notwithstanding, however, this disuse of them in actual warfare, the subject has received considerable attention at different periods from distinguished Engineers; and systems (as they are termed) of countermines are consequently very numerous. Among the most celebrated of these systems are those of Goulon, Vallière, Mesgrigny, Delorme, Cormontaigne, Rugi, Mouzé, Dubuat, and Marescot. The object of the Engineer, in each system, appears to have been so to dispose his subterranean works as to destroy the various surface approaches of the besieger when in advance of his third parallel; but more particularly the breaching batteries he establishes on the crest of the glacis.

A brief notice of the various circumstances under which, at different periods, mines have been employed in war, will properly preface the present article. Their earliest application appears to have been made in the *Attack*, and simply for the purpose of gaining access into the interior of fortified towns by means of a subterranean gallery passing under the walls of the fortress. The obvious inconveniences attending such a mode of attack soon occasioned its disuse, but a more successful employment of mining followed; viz. by continuing the galleries only as far as the foundation of the principal wall, and then, by excavating the ground for a certain breadth (say about 100 feet) under its base,—the masonry being temporarily supported by wooden props,—the wooden supports were set fire to when the arrangements were ready for the assault: the wall, being left without support, necessarily fell, and opened a breach to the besieger.

The introduction of mines in the *Defence* naturally followed their employment in the *Attack*. The earliest subterranean defensive position consisted of a gallery placed in advance of the foot of the wall, and termed an envelope gallery. From this gallery, the garrison pushed forward small branches or galleries for the purpose of being warned of the approach of the enemy, and by these means to prepare themselves to resist his attack. The defenders occasionally employed these subterranean defences for overthrowing the towers, battering-rams, and other offensive weapons of the besieger. It may be remarked here, that from the circumstance of mines having been introduced in the Defence, after the employment of them in the Attack, and for the purpose of counteracting their action, the term *countermine* was given to defensive mines by the Engineers of that time; and the name, although apt to mislead, is still retained: some writers, however, apply the terms 'offensive and defensive mines;'—these latter designations appear the most appropriate.

Such was the nature of subterranean warfare previously to the invention of gunpowder; and, what is remarkable, almost two centuries elapsed between its invention and the use of it in mines. The circumstance under which the first mine charged with powder was exploded is thus narrated by Bousmard.

"The French, under Charles the Eighth, in 1503, having overrun with great rapidity the kingdom of Naples, were as quickly dispossessed of their conquest by the Spaniards, under the famous Gonsalvo di Cordova, surnamed the Great Captain. A single post, defended both by nature and art, alone remained in possession of the French, and resisted for three years the united efforts of the Spanish and Neapolitan armies to reduce it: this was the castello del' Uovo, in the Bay of Naples, constructed on a rock surrounded on all sides by the sea, except where a narrow isthmus formed a connection with the main land; across which isthmus, however, a deep ditch or *coupure*, cut in the rock, prevented all access into the interior. The natural defensive advantages of the position account for the protractedness of the defence. The ingenuity of a Spanish Captain, Pedro Navarro, gave at length the victory to his countrymen. He took advantage of the contour of the rock to open, unseen from the castle, a gallery which he contrived gradually to drive forward till it had arrived under the castle; and then placing a quantity of powder, he ignited it by a process

which allowed the miner who applied the quick-match time to escape. The explosion caused a violent commotion of the rock; great masses of it, together with a portion of the walls of the castle and a large proportion of the garrison, were precipitated amidst flame and smoke into the sea. Then the élite of the Spanish and Neapolitan armies landed from boats, and easily carried the breach made by the mine, but weakly defended by a small number of the garrison, already dispirited by the consternation produced by the explosion." Such was the success of the first experiment in mines charged with powder.

It appears that the success which attended this mode of destroying defensive works soon caused its very general employment: at the close of the fifteenth and at the commencement of the sixteenth centuries access into fortresses was very generally made by mines; and indeed so powerful at this time seems to have been their influence in the attack, that it was not unusual for the besieger, after preparing his mine, to invite the besieged to inspect it, with a view of inducing the latter at once to surrender.

To return, however, to the Defence: the galleries which had been employed previously to the invention of gunpowder were found to possess certain unlooked-for advantages after the introduction of its use in offensive mines. It was observed that when a charge of powder was exploded in their vicinity, its surface effect was very much diminished: under such conditions the mine was said to be éventée,—'éventer la mine.' The old galleries also retained their original purpose of informing the besieged of the proximity of the enemy, of enabling him occasionally to break into the gallery, and of destroying the works.

The first application of powder in defensive mines consisted of small charges; the explosion of which, without causing any surface effect, ruptured the besieger's gallery, and suffocated its occupiers: this operation was called 'giving the camouflet to the enemy's miners.' From the employment of camouflets to the introduction of more powerful mines was but a step.

By the explosion of larger charges, not only were the surface approaches of the besieger for a certain distance destroyed, but his galleries, which were at a less distance from the powder than the surface of the ground, were likewise blown in: so soon as defensive mines were thus far perfected, the employment of powder in subterranean operations, which at first certainly favored the attack, became a powerful auxiliary to the defence. It is obvious, that when the besieged had, beforehand, arranged a system of galleries under his glacis, he must necessarily possess many advantages over the besieger, who has to construct his subterranean approaches in ground already occupied by the mines of the besieged. The attack, in place of advancing simply by furrowing the surface of the glacis, was now compelled to engage in under-ground operations, the progress of which must necessarily be slow and the issue uncertain: superiority of force no longer availed the besieger, while the surface attacks, brought almost as far as the foot of the glacis, became for a time stationary, and exposed to the near fire of the musketry of the fortress.

To increase still more the advantages of defensive mines, various modes of placing them were proposed for destroying the cavalier of trenches, for overthrowing the breaching batteries of the attack, and for blowing the guns into the ditch. Systems of defensive mines, arranged on different stages, were likewise proposed, with the object of destroying the same works of the besieger several times in succession.*

The experiments of Belidor caused, however, these complicated systems to fall into disuse, and deprived defensive mines generally of some of the advantages they had hitherto possessed. To Belidor is due the discovery, that, by the employment of

† This mode of attack was prior to the invention of globes of compression.—*Editors.*

large charges, the galleries of the besieged could be destroyed from a considerable distance. Before his time, it had been generally conceived that no crater the diameter of which exceeded twice its depth, could be formed by the explosion of a mine, and the interior effect was also supposed to be proportionally limited; but so soon as the fallacy of this opinion had been exposed by Belidor, who proved that the radius of the rupture with large charges much exceeded the limit usually assigned to it, the attack received considerable advantages. The besieger availed himself of this long weapon, and, by means of it, cleared the ground for a considerable distance around him, not pushing his galleries within the much narrower circle of the mines of the besieged. This, however, will be more particularly explained in the 'Attack of a System of Defensive Mines.' J. W.

Note.—The subject will be treated under the following parts or divisions: 'Practical Operations of Mining,'—'Charges of Mines,'—'System of Permanent Defensive Mines,'—' Attack and Defence of a System of Defensive Mines.'—*Editors.*

PART II.—PRACTICAL OPERATIONS OF MINING.*

The essential difference between Civil and Military Mining is, that in the former the works are for the most part carried on at greater depths below the surface of the earth, and in solid rock; whereas military mining is what may be termed superficial, and consequently the miner works through the more recent formations of earths and sands, which, from their little tenacity, he has to support as he advances with wooden linings: it is in the adjustment and fittings of these linings that the chief art of the military miner consists. †

The excavations made by military miners are, when vertical, called Shafts; when horizontal, or when slightly inclined, and exceeding in dimensions 3 feet by 4 feet, Galleries; when under these dimensions, Branches: when galleries or branches are inclined, they are called ascending or descending, according to the direction of their inclination.

The galleries and branches of a system of mines, forming part of the defences of a fortress, are usually revetted with masonry: their construction and detail will not be included in this part of the subject, but will be explained in the 'System of Permanent Defensive Mines,' (Part IV.)

The annexed Table gives the names and dimensions of galleries and branches employed in mining operations.

NAME. Description of Gallery or Branch.	Dimensions in the clear.	Scantling of Frames.		
		Groundsill.	Stanchions.	Capsill.
	Height. ft. in. Width. ft. in.	inches.	inches.	inches.
1. Great gallery	6 6 × 7 0	6 × 3	6 × 6	6 × 8½
2. Principal gallery ...	6 6 × 3 9	5½ × 3	5½ × 5½	5½ × 8
3. Common gallery....	4 6 × 3 0		5 × 5	5 × 6½
4. Great branch	3 6 × 2 6		4 × 4	4 × 5
5. Small branch	2 6 × 2 0		3 × 3	3 × 4

1. Those galleries used for descent into ditches and the passage of cannon.

* By Captain Wynne, R.E.

† This part is based upon the practical course taught at Chatham.—*Editors.*

2. Those used for descent into ditches and the passage of troops, two deep.

3. Sufficiently large for all the general purposes of attack; and as it allows the miner a free change of posture, either to work kneeling on both knees, or on one knee, with the right or left foot advanced, he works without feeling cramped, and executes this size more rapidly than any other.

4 and 5. Too small to work in for a greater distance than 10 or 12 feet.

TOOLS REQUIRED FOR MINING OPERATIONS.

Plate I.

Pickaxe (common).
Do. (short-handled), fig. 1.
Shovel (common).
Do. (short-handled), fig. 3.
Push-pick, fig. 2.
Rake, fig. 6.
Canvass bucket.
Windlass and rope (2-inch).
Rope ladder.
Wooden wedges and pins.
Do. pickets.
Miners' waggon, fig. 5.
Wheelbarrow.
Iron candlestick, fig. 7.
Lamp (miners').
Lantern.
Oil can.
Measuring tape.
Compass.
Universal level, fig. 4.
Hand-saw.
Mallet.
Hammer (claw).
Rough plane (¼-inch).
Chisel.
Gimlet.
2-foot rule.
Plumb-bob.
Boring-rods.
5-foot rod.
Bellows (miners').
Ventilating tube.
Flexible joints.
Needles, threads, scissors.
Calico for hose.
Hatchet.
Tin funnel (for filling hose).
Rammers (short-handled).
Helves (spare).
Sand-bags.

WOODEN LININGS.

It has already been stated that the military miner, from the loose or made soil in which he generally works, has, as he advances, to support with wooden linings the top and sides of his excavation; in some soils, the earth is of sufficient tenacity to require only, that in driving galleries in it, their top should be supported. But in sinking shafts it is always advisable, unless their depth should be very little, to line them with boarding throughout, or at least partially.

In describing the process of driving a gallery, the soil is supposed to be of that nature which renders close casing desirable.

There are two methods adopted at the Royal Engineer Establishment at Chatham for lining shafts and galleries. The first is with mine frames, which, in appearance, are similar to door frames, being cut out of scantling, and placed upright or horizontally at certain intervals in the gallery or shaft, as the case may be, and which serve as supports to planks called sheeting planks, or sheds, which are placed all round between the frames and sides of the excavation. The second is with cases, which, instead of being made from scantling, are formed out of wood plank, about 2 inches thick and 1 foot wide: these are placed close together, and serve at once for frames and sheeting. The advantage of this latter method in saving excavation, and consequently expediting the work, is at once obvious; besides which, the facility of fixing them up is much greater: these and other collateral advantages have been so much felt at the Engineering Establishment at Chatham, that cases

have quite superseded mine frames in the practice there; but as circumstances may occur which render it more convenient to use frames and sheeting than cases, both methods will be described, commencing with the former.

SINKING SHAFTS WITH FRAMES.

Shaft frames are composed of four pieces, two of which are long and two short.

The long pieces are of the same uniform section throughout; the short pieces are notched at each end, so as to form shoulders for the long pieces to abut against. (See figs. 1 and 2.) The depth of these notches is made equal to one-third of the width of the piece.

Fig. 1.

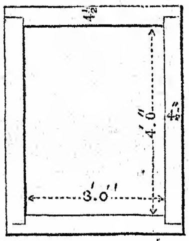
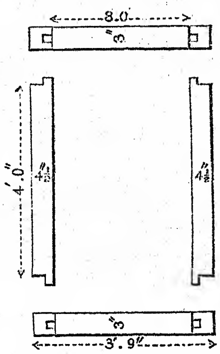


Fig. 2.



To prevent the parts from separating, the long pieces are made with tenons,* and mortises are cut in the short ones, close to the shoulders, to receive them.

As the tenons or dowels are merely for the purpose of steadying pins, the smaller they are the better, provided they are not liable to break; and they must not be so tightly fitted into the mortises as to prevent the proper bearings and abutments of the parts of the frame against each other: with the same view, it is also essential that each tenon or dowel shall be flush with one side of the piece to which it is attached, and that the mortises shall be cut quite close to the shoulders of the other pieces: the pressure on the frame being lateral, the width of each piece should exceed its depth; 3″ by 4½″ will be found sufficient for all shafts not exceeding 3 feet by 4 feet; and this size (3 × 4½) is probably the largest that would ever be required in field operations. For temporary purposes, 4″ by 6″ will be sufficient for a shaft 6 feet in extreme width.†

In addition to the common shaft frames before described, it is proper to have one expressly for the top of each shaft; its dimensions in the clear are the same as those of the common frames, but the ends of the two long pieces are made to project about 1 foot each way (fig. 3): the parts of this description of frame are connected by tenons and mortises which are equal in length and width to the whole width of the wood, but in depth to one-third only: the same scantling may serve both for the top shaft frame and the common ones, but not without reversing the position of the pieces; for in the top frame the depth should be greater than the width.

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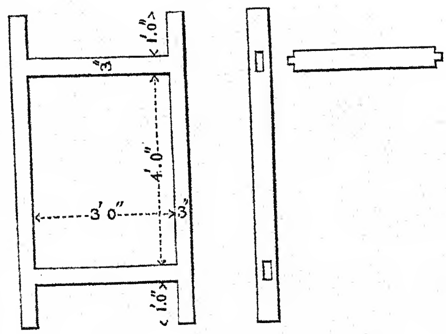
* Dowels of a harder description of wood may be inserted instead of tenons, and they render the frame more serviceable.

† Each one of the four parts of the frame should be notched in its centre on the inside: these notches assist materially afterwards in the proper adjustment of the frame.

The sheeting for shafts should be of plank from 1″ to 1½″ thick; the planks are usually chamfered at one end, to admit of their being more easily pushed forward; their length will depend on the distances at which the frames are placed, which, on an average, may be assumed to be 4 feet: the planks may therefore be cut in lengths of 5 feet, which will allow the necessary overlap.

Fig. 3.



MEN AND TOOLS REQUIRED FOR SINKING A SHAFT.

MEN.		TOOLS.													
		Picks.		Shovels.											
N. C. Officers.	Privates.	Short.	Push.	Long.	Short.	Line.	Level.	Measuring rod.	Mallet.	Canvass bag.	Rope ladder.	Wheelbarrows.	Windlass.	Miners' trucks.	Ventilating apparatus.
1	9	1	1	2	2	1	1	1	1	1	1	2	1	2	1

It has been found that one man can work in a shaft not less than 4 feet in depth, and throw out earth until it is 8 or 9 feet deep; after which the earth is drawn up in a canvass bag by two men at top, by means of ropes attached to each of its handles: should the depth become great, a windlass and bucket must be substituted.

The disposition of the workmen is as follows:

1 man excavates and fills the bag.
2 men haul up or work the windlass.
1 man fills the wheelbarrow.
1 „ wheels.
1 „ spreads, to prevent an accumulation which might attract observation.

Two gauges or rods for the extreme dimension of the rectangle of excavation are to be provided: these two rods must respectively exceed the true exterior dimensions of the shaft frame in length by about 6 inches (3 inches on each side), in order to admit of two* thicknesses of sheeting planks being introduced all round, between the frame and sides of the excavation.

The top shaft frame having, when placed, only one thickness of sheeting planks round it, the rectangle of excavation must be marked on the ground rather less than the dimensions of the gauges. When the shaft is intended to be sunk with a view to the commencement of a gallery, care must be taken that the long sides of this rectangle shall agree with the direction of the proposed gallery.

The distance at which the floor of the gallery is to be placed below the surface of

* It may be necessary to explain that each set of sheeting planks must project a few inches above and below the two adjoining frames; so that each frame, with the exception of the top one, has necessarily two sets of planks between it and the earth.

the ground being given, the first thing to be done is to determine the distance to be left between the frames. To find this, let us suppose that a common gallery, 4 feet 6 inches high in the clear, is to be driven from the bottom of a shaft 25 feet deep:

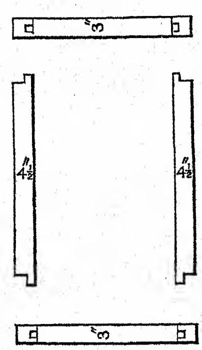
	ft.	in.
Then the height of the gallery from the floor to the top of the capsill being	5	1
Thickness of top sheeting	0	2
Free space for introduction of do.	0	2
Thickness of shaft frame next above the gallery	0	4½
	5	9½

The top, therefore, of the frame above the gallery must then be 5 feet 9½ inches from the bottom of the shaft. Subtract this from the total depth of 25 feet, there remain 19 feet 2½ inches. There would then be required four intervals of 4 feet each, and one of 3 feet 2½ inches for the last interval. To find the length of the last set of sheeting planks, the thickness of one frame and an overlap of 2 inches must be added to 5′ 9½″, making 6′ 4″.

An excavation of the size of the rectangle previously marked must then be cut vertically down to the depth of 2 or 3 feet; after which, one of the top shaft frames, before described, is placed correctly over the excavation, the projecting pieces preventing it from falling down: this frame is generally placed flush with the surface of the ground. The excavation is then continued to the depth of 4 feet, when a common frame is put together, and laid horizontally at the bottom of the shaft, with its corresponding sides vertically under those of the upper frame: the excavation at this level must be fully equal to the dimensions indicated by the gauge rods. A plumb-bob is necessary to preserve the verticality of the excavation, as well as for the adjustment of the successive shaft frames by means of the notches before noticed. As soon as the second frame is placed,* the first set of planks are pushed vertically downwards, with their pointed ends foremost, between the earth on each side and the top frame.

At top, each of these planks is pressed home close to the top frame, but at the bottom it is kept out from the lower frame by wedges rather thicker than the plank itself. The two frames are then connected together by four ties of wood, which are thin laths, about 2 inches wide, extending vertically from one frame to the other, being nailed to each: sometimes rope is used, in which case it is made to pass through holes bored in the frames, and a knot on the rope, or a picket between the strands, immediately under the lower frame, prevents it from falling.

Fig. 4.



After the first two shaft frames and one set of sheeting planks are thus placed, and the frames connected, the excavation is continued about 4 feet deeper, when another frame is placed with the same care: a second set of planks is then introduced between the first set and the second frame, after removing the wedges which were before inserted: in order to preserve room for them, these new planks are pushed down to the bottom of the shaft, and are there separated from the lower shaft frame

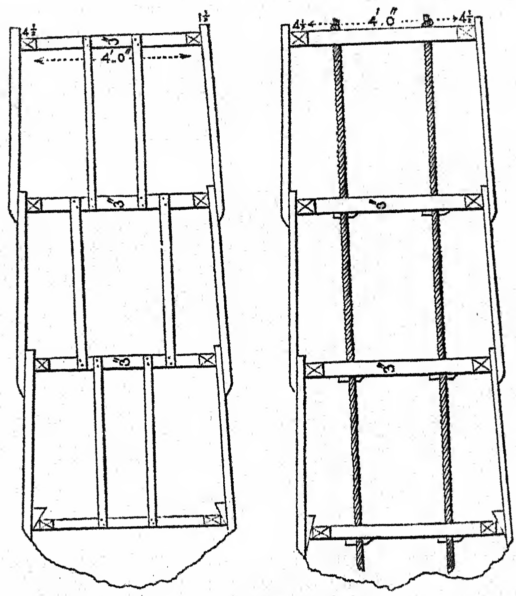
* It will seldom be found necessary to close-sheet a shaft; generally two planks on a side will be sufficient. For shafts of moderate depth, and for hasty explosions, woodwork may generally be dispensed with altogether, even in earth of no great tenacity. But when the soil is favorable, shafts of 20 or 30 feet in depth may stand for several weeks. In excavating a shaft in which no woodwork is to be used, the elliptical form is decidedly the best.

by wedges, as before described. Thus the work goes on until the miner arrives near the level of the top of the proposed gallery, when the last shaft frame must be placed at the calculated interval. This being attended to, the excavation is continued down to the bottom of the intended gallery, when another shaft frame is placed so as to have its upper surface on a level with the floor of the gallery. Three sides only of this part of the shaft must now be sheeted, and without wedging out the planks which are to rest against the bottom frames: the fourth side of the shaft being left clear for the entrance of the gallery on this side, the outline of the gallery is traced.

DRIVING GALLERIES WITH MINE FRAMES.

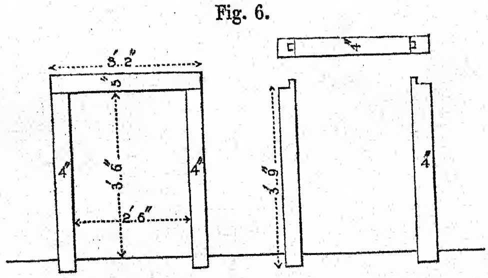
Gallery frames differ from shaft frames in being composed of three pieces only; namely, two uprights, called stanchions, and one top piece, called the capsill. The

Fig. 5.



stanchions are usually let into the ground a few inches, and the capsill afterwards laid over them. The stanchions have square tenons at top, flush with the inside of

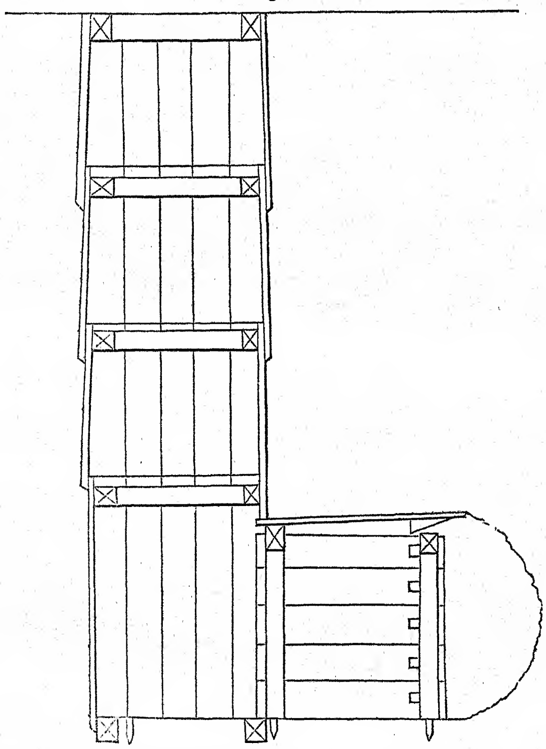
Fig. 6.



each, which are inserted into mortises cut in the lower side of the capsill. The

stanchions are usually cut out of square scantling; the tenon is made equal to one-third of the side each way, and in height to one-fourth. The scantling for the stanchions of a branch may be 4″; for a gallery 3 or 4 feet wide, $5\frac{1}{2}''$ or 6″. The capsill is usually made of the same width as the stanchions, but somewhat deeper for the sake of strength, the chief pressure being vertical. In branches and small galleries an excess of about one-fourth will be sufficient; in the wider galleries the excess may amount to one-third or even one-half. The side sheeting of galleries may be of 1″ or $1\frac{1}{2}''$ plank; for the top sheeting it should be from 2″ to $2\frac{1}{2}''$.

Fig. 7.



Great gallery frames have their stanchions of scantling $5\frac{1}{2}''$ or 6″ square, and their capsills 8″ by $5\frac{1}{2}''$ or 8″ by 6″: the tenons at the head of each stanchion should be $1\frac{1}{2}''$ square and $1\frac{1}{2}''$ long. We shall now proceed to describe the method of driving the gallery from the bottom of a shaft, and we shall consider the ground to be such as to render it necessary to sheet the sides as well as the top.* The first thing necessary is to prepare two rods as gauges for regulating the height and width of the excavation: the gauge for the height must allow beyond the extreme dimensions for two thicknesses of plank, and that for the breadth for four

* Although it has been thought advisable to describe the mode of driving a gallery under circumstances which render it necessary to close-sheet the top and sides, it will in most instances be found sufficient (except in the case of great galleries) to sheet only the top: when this is the case, the stanchions of the frames are let into grooves cut in the sides, and by this arrangement a considerable quantity of excavation will be saved.

thicknesses of plank, two on each side of the frame; and the latter, *i.e.* the gauge, must be notched or otherwise conspicuously marked in the centre. It was stated before, that in sinking a shaft the long sides of the frames must correspond with the direction of the gallery intended to be driven from the bottom: if this has been carefully attended to, the direction of the gallery will be at once obtained by dropping plumb-lines from the centre of each of the short pieces, and marking these points at the bottom of the shaft with pickets; or the notches on the bottom frames, if accurately laid, will be sufficient. In commencing the gallery, the excavation may be carried forward about 1 or 2 feet before the first frame is placed; the entrance made in the first instance should be less, both in width and height, by the thickness of one set of planks, that is, by $1\frac{1}{2}''$ on each side and $2''$ on the top; the exact position of the first frame being ascertained by laying the gauge so that the notch in its centre may coincide with the picket at the entrance of the gallery. The stanchions are first set up with their lower ends inserted a few inches in the ground; the plumb-bob being used to set them perpendicular, the capsill is placed on them, and the frame secured in its upright position by being wedged out from the top and side.

This being completed, the excavation is continued to the distance of about 4 feet, when the position of another frame must be determined. This is done by stretching a line over the two pickets, or fixed points, before determined, and then driving a third picket in the floor, to mark the centre spot of the new frame. If the gallery is a horizontal one, the top of this picket should be made exactly level with the picket at the entrance; if a descending one, the top of it should be the requisite number of inches below the first picket: this, being accurately done, will be a point to measure from for the height of the under side of the capsill. At this point the gallery must have been gradually widened to the full dimensions of the gauges.

The frame is set up in the manner before described; and in order to secure its proper horizontal position, it must be raised or lowered, as may be required, until the bottom of its capsill is at the same height from the ground as the capsill of the first frame: the common level reversed, with its plumb-bob shifted, must then be applied to the under side of the capsill. If the capsills of the first two frames are carefully placed, the other will be easily adjusted by being made to line with them. The top sheeting planks* having been introduced over the first frame, with their pointed ends foremost, are now pushed forwards until they rest also upon the capsill of the second frame; wedges are then introduced, as in sinking a shaft, and the side sheeting is pushed on in an exactly similar manner.

MEN AND TOOLS REQUIRED FOR DRIVING A GALLERY FROM THE BOTTOM OF A SHAFT.

MEN.		TOOLS.										
		Picks.		Shovels.								
N. C. Officers.	Privates.	Short.	Push.	Long.	Short.	Line.	Level.	Measuring rod.	Mallet.	Canvass bag.	Rope ladder.	Wheelbarrows.
1	6	1	1	2	1	1	1	1	1	1	1	2

* If the shaft be only 4 feet in the greatest dimension, and the sheeting planks 5 feet long, they must be got into their position from within the gallery.

The disposition of the workmen is as follows:

1 man picks.
1 „ fills the truck.
1 „ wheels.
1 „ fills the bucket at the bottom of the shaft, or attaches the truck to the windlass.

5 men are employed at the top of the shaft, as stated before.

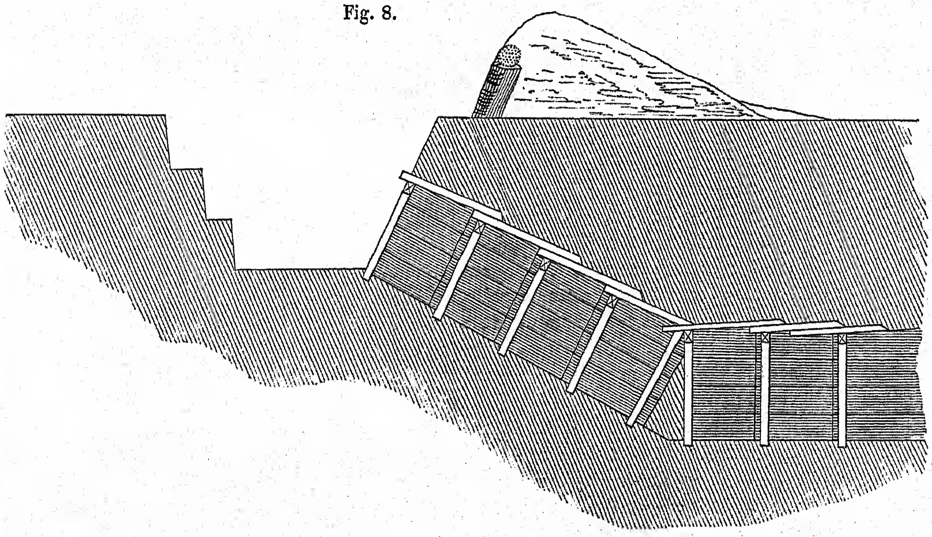
For every 50 feet driven, an additional man and truck become necessary, recesses being cut at the sides to receive the empty truck while the loaded one passes: one additional man will also be required at top, to work the ventilating apparatus. Instead of using a bucket for hoisting up the earth, it is found to be a more expeditious plan to attach the full truck to the windlass. Where the gallery is unconnected with a shaft, the two men working the windlass might be struck off. In great galleries the earth may be removed in wheelbarrows.

Whenever there appears to be any risk of the soil falling in, it is proper, after placing each successive frame and excavating 1 or 2 feet beyond it, to remove the wedges, and to introduce the next set of top sheeting planks, as far as they will go, without waiting for another frame, and to push them forward as the excavation proceeds. Thus the man excavating will always work under cover of these planks.

INCLINED GALLERIES.

When the depth required to be reached is not great, it will generally be found more convenient to obtain this object by making a descending gallery in preference to striking out from the bottom of a shaft. A gallery is never made to descend more than 1 foot in 2. A descending gallery may be commenced from behind some bank or natural cover, or from behind a parapet; as for example, from one of the most advanced parallels or lodgements in a siege. It may not always be convenient to commence a gallery, when required in a siege, from one of the regular parallels or lodgements; in such cases a small parallel may be made for the purpose, and connected with the nearest trenches by a boyau. When a descending gallery is

Fig. 8.



commenced from a parallel, the trench of the parallel must be deepened at the spot chosen for the entrance of the gallery, as much as may be necessary to allow the top of the excavation of the gallery to be 2½ or 3 feet below the original surface of the ground. The execution of the gallery is to all intents the same as that of a horizontal one, except that the frames are set up perpendicular to the slope, and the distance between any two must be measured along it. This being attended to, the same sheeting will answer, whether the gallery is inclined or horizontal. The first frame of an inclined gallery ought, as nearly as possible, to be under the terre-plein of the banquette. It is to be observed that the pressure of loose earth acting upon the roof of a gallery will always tend to overset the mine frames, unless the latter are placed in a direction perpendicular to the floor of the gallery, or nearly so.

In changing from a descending direction to a horizontal one, it is necessary to change also from oblique frames to vertical ones, and it becomes also necessary to support the first vertical frame by struts placed parallel to the stanchions of the oblique frames in rear of it. Thus the capsill of the first vertical frame is as it were supported by two pairs of stanchions, one pair vertical and the other oblique, in order to resist the double action of the loose earth immediately above it, which presses vertically upon the top sheeting of the first horizontal bay, but obliquely upon the top sheeting of the last inclined bay of the gallery.

GREAT GALLERIES,

if executed in bad soil, require some precautions to be taken which may be dispensed with in smaller excavations. The following may be found generally essential.

1st. Sleepers or groundsills should be laid beneath each of the regular gallery frames, to prevent the stanchions from sinking unequally. These groundsills, when required, may be cut out of 3-inch plank. In width and length they must be exactly equal to the capsills of the regular frames: they are always inserted their own depth in the earth.

2ndly. It was before explained, that in bad soil the top sheeting should be invariably pushed forward, in proportion as the excavation proceeds. Now whilst this projection does not exceed a foot or two, no inconvenience arises; but when it exceeds the last-named dimension, the great weight of loose earth acting upon the extreme ends of the planks will often derange them in such a manner as may impede the work, or even cause some serious failure. This difficulty is obviated by using a temporary frame, called a false frame, for supporting the projecting ends of the top sheeting until the roof of every new bay of the excavation is properly secured. The false frame should be of the same height as the regular gallery frames, but it must be so much narrower that its width from out to out shall not exceed the width in the clear of the latter. Its capsill must be of the same depth, but its stanchions must be made of rather smaller scantling than those of the common frame, for the sake of lightness. The method of using a false frame is as follows: as soon as one of the regular or permanent gallery frames is fixed, the excavation is carried forward to the distance of about 1 foot, or even less, according to circumstances, and in no case exceeding 2 feet; after which a false frame is placed in the same manner as a common one. The top sheeting is then pushed forward until it rests upon the capsill of the false frame: the miner then excavates a little further, and pushes forward the top sheeting as he goes on, taking care that it never shall project more than 6 inches, or thereabouts, beyond the false frame, which he must also move forward as the excavation proceeds. As soon as the excavation has advanced to such a distance that another regular frame is required, instead of moving the false one further on, a regular gallery frame is placed, and the

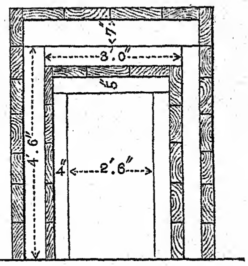
same sheeting which rested on the false frame is urged out from it in the usual manner, and the frame removed, for the purpose of being again used in advance. It is to be observed that the false frame, when first placed, must stand about 2 inches higher than the proper position of one of the regular frames, in order that the sheeting, in being pushed or driven towards the head of the mine, may acquire the proper splay upwards without wedges, which it is impossible to use with a false frame during this operation; and for this purpose the stanchions of the false frame must be 2 inches longer than those of the regular ones.

BRANCHES.

In a system of military mines the branches are merely smaller galleries than usual, branching out from the common galleries: hence their name. As the construction of both is so much alike, it is only necessary to notice the circumstances under which a branch proceeding from a gallery may be commenced.

1st. A branch may be excavated in the same direction and in continuation of the gallery itself. In this case the first branch frame must be placed immediately beyond the last gallery frame, and close to it; or, if there be room, it may be placed exactly within it, the centre of both coinciding, as in the annexed figure.

Fig. 9.



2ndly. A branch may be cut at right angles to the gallery from whence it proceeds. In this case the mode of commencing is the same as excavating a gallery from the lower part of one side of a shaft, it being understood that the floor of the branch always commences from the bottom of the gallery. The entrance of the branch is of course cut half-way between two adjacent gallery frames.

3rdly. A branch may be commenced obliquely from the side of a gallery:

Fig. 10.

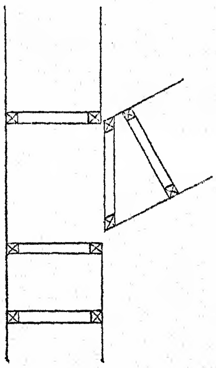
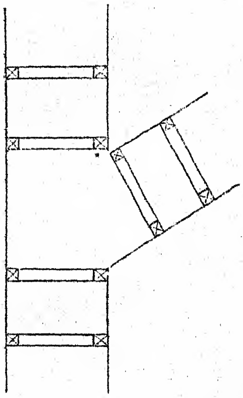


Fig. 11.



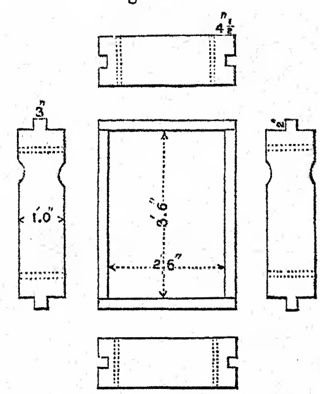
In this case, if the soil be good, and not wanting much support, the first branch frame is placed as near to the side (see fig. 11) of the gallery as possible, but at right angles to the direction of the intended new branch. Hence one stanchion only of the first branch frame can agree with the side of the gallery; the other side will be more or less distant from it, in proportion to the degree of obliquity.

If, on the contrary, the ground cannot be trusted, the first branch frame must be placed so as to line with the side of the gallery itself (see fig. 10), and consequently a longer capsill than the ordinary ones will be required.

MINING WITH CASES.

Having described the method of mining with frames and sheeting, it remains now to point out the difference when mine cases alone are used. These descriptions of cases have long been known under the name of Dutch cases: they were introduced into our Service by Major-General Sir C. Pasley, when Director of the Field Instruction Establishment: these consist of four pieces,—two stanchions, a capsill, and groundsill. For ordinary work they are made out of 2-inch deal, and have a ⅝-inch round iron bolt driven transversely through the middle thickness of the wood of each piece, about 4½ inches from each end, to prevent them from splitting. The stanchions have tenons 2″ long by 3″ wide at each end, and mortises of corresponding dimensions are cut in the ends of the capsill and groundsill to receive the tenons: the most convenient width for the piece would be 12 inches, but this is not a matter of consequence (as 12-inch is not easily procured), and they may be made of whatever sized planks, not less than 2 inches thick, that can most readily be procured. In great galleries, which require stronger materials, the stanchions may be 4 inches thick, the groundsill 3 inches, and the capsill 5 inches: notches, as shewn in figure, are cut in the stanchions, for the purpose of rendering them more manageable, both in putting them up and taking them down; they also serve for places in which to drive pickets to support the case in a descending gallery. The size of cases, in the clear, both for shafts and galleries, is the same as that of frames, and the same precautions and arrangements in their adjustments are necessary.

Fig. 12.

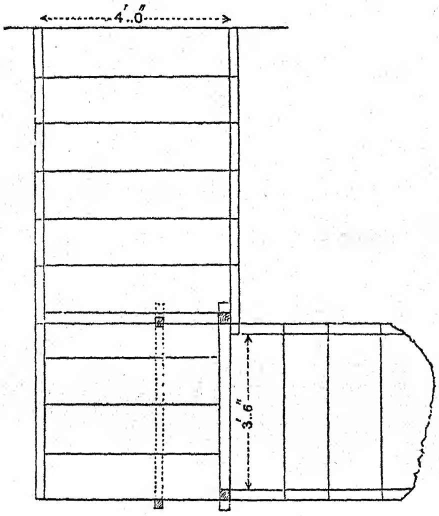


In sinking shafts, when the excavation has advanced about 1 foot in depth, it becomes necessary to fix the first case, which is done in the following manner. One of the short pieces is first placed in its proper position in the excavation; the tenons of the two long pieces are then fitted into the mortises of this, and then the mortise at one end of the fourth side is fitted on its tenon; but to adjust the corresponding mortise and tenon, it will be necessary to push back either this short piece or the long one full 2 inches, in order to bring the mortise and tenon together; and whichever plan is adopted, as little earth as possible should be cut away. The first case being placed, the excavation is proceeded with, and the second case is placed close under the first, and in a similar manner, and so on to the bottom of the shaft. This is the mode of proceeding when the soil is so bad as to require close casing; under ordinary circumstances, however, it will be sufficient to introduce a case at every 3 or 4 feet; and when this is done, it is usual to cut out the earth to the thickness of the plank, so as to admit of the case being placed flush with the sides of the excavation.

When it is intended to push a gallery from the bottom of a close-cased shaft, it is evident, before proceeding, it will be necessary to remove one side of the casing; and

to do this without causing the adjacent side to collapse, and the casing to tumble in, a frame somewhat similar to a door frame must be introduced: its groundsill being

Fig. 13.

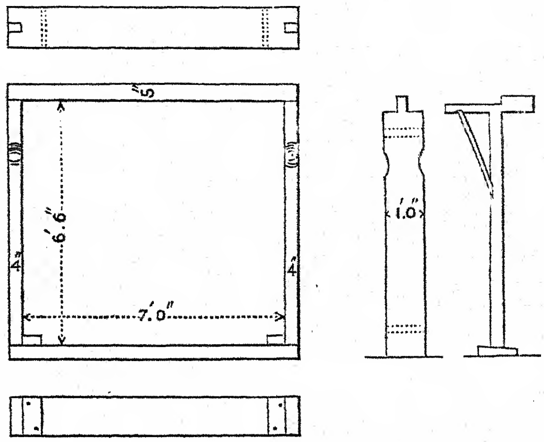


adjusted so that its upper side may be on a level with the floor of the intended gallery, the exterior dimensions of the frame must exactly correspond with the width of the shaft, and the interior dimensions may be exactly those of the gallery, or exceed them by an inch or two. When this frame is first put up it should be made to stand about 1 foot from the side of the casing which is to be removed; and when this is effected, it must be forced up against that side. These details having been attended to, the casing on the side from which the gallery is to start may be removed, commencing with the side of the lowest case, to remove which will be a work of some difficulty: as the earth must be picked away from behind it, in order to admit of its being pushed back to clear it of its tenon, it will be necessary, in the first instance, to excavate the ground underneath it, in order to admit of the introduction of the pick and push-pick, but the removal of each successive side will be easier. In driving the gallery, the mode of using the cases is as nearly similar as possible to that described for shafts, making allowance for the difference of direction: the groundsill is first placed next the stanchions, and to fix the capsill the same mode of proceeding is to be adopted as has already been described for fixing the fourth side of the shaft case: the space which is necessarily left between the earth and the top of the capsill should be filled in before proceeding to place the next case. Close casing will seldom be required in a gallery, but the roofing should in most cases be supported: this can easily be effected by using pieces of the cases as top sheeting, extending from the top sides of the cases which it may be found necessary to use.

Great gallery cases are somewhat different from other cases. In order to give greater strength, the stanchions are made without tenons at their lower ends, which are kept in their places by cleats 2 inches thick, nailed on to the sills: the mortises in the capsills need not be more than 2 inches deep. In driving great galleries in loose soil, after setting up the first frame it becomes necessary to support the topsill whilst the miner excavates the ground for the groundsill and stanchions. For this purpose

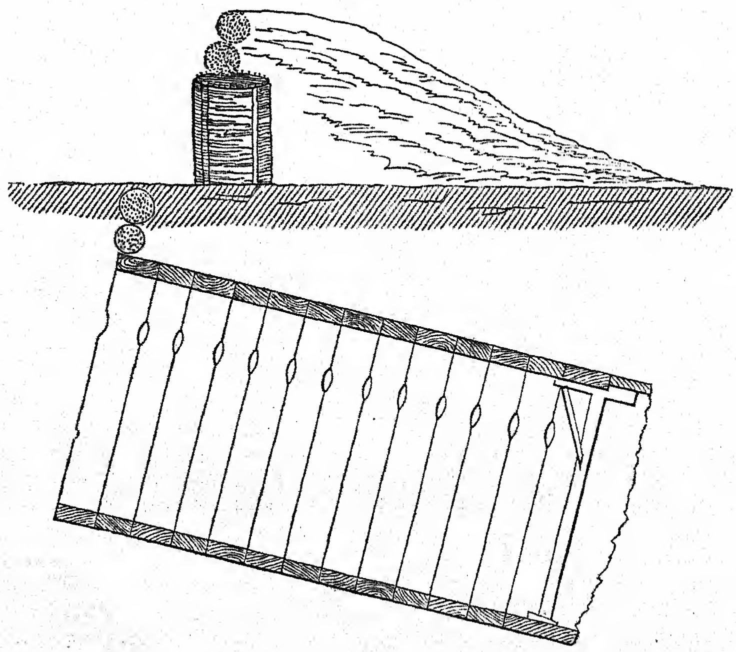
two upright pieces of timber, carrying each a cross-piece, as represented in the annexed figure, are made use of. The upright part rests on the sill of the frame already placed, and is steadied by being wedged up. The cross-piece is 2 feet long,

Fig. 14.



and the part that projects in advance, as will be seen from the figure, is made an inch higher than the rear part, to support the topsill somewhat higher than its final level. The rear part of the cross-piece is braced by a piece of iron to the upright.

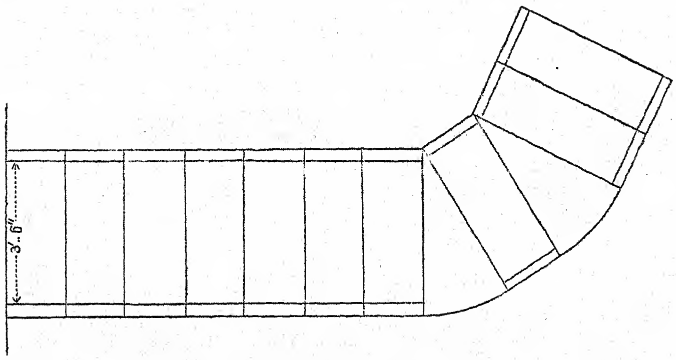
Fig. 15.



These are called crutches, and the materials of which they are made should be as light as a due regard to strength will admit.

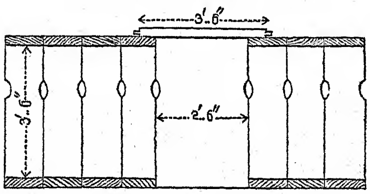
In working with cases, the direction of a gallery may be easily and gradually changed, as shewn in figure 16.

Fig. 16.



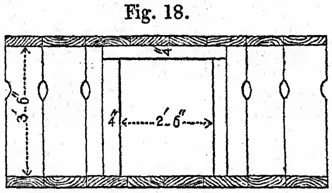
If the soil is good, the intervals which occur between the cases may be left open; if bad, they may be filled up with small pieces of wood. When it is necessary to break out from the side of a gallery in a direction perpendicular or oblique to it, the requisite number of cases must be removed, and the roof of the interval lined with pieces of board extending across and supported on the extreme cases. See fig. 17.

Fig. 17.



If the soil is very bad, the stanchions only from the side whence the new gallery is to proceed need be removed, and the intervening capsill can be supported as in fig. 18. But this method has the inconvenience of lowering the headway,—a serious objection.

Fig. 18.



When a gallery branches from another in an oblique direction, it will be better to obtain the obliquity gradually, than by introducing an oblique case, like the frame indicated in fig. 16.

When cases are used, the work will advance at nearly double the rate it would with frames and sheeting: viz. great galleries and shafts about 1 foot an hour; common galleries, 1½ foot an hour.

PART III.—CHARGES OF MINES.*

When charges of gunpowder are fired under the surface of the ground, the effects caused by their explosion are necessarily dependent on the quantity of powder used, on the depth at which they are placed, and on the qualities of the soil in which the explosions take place.

* By Captain J. Williams, R. E.

When, by the explosion of a charge of powder, a circular excavation is formed on the surface of the ground, the radius is called the radius of the crater. The line drawn from the charge perpendicular to the surface is called the line of least resistance. The line drawn from the charge to the edge of the crater is called the radius of explosion. A crater of which the diameter is equal to the line of least resistance is called a one-lined crater; when the diameter is double the line of least resistance, it is called a two-lined crater; when triple the line of least resistance, a three-lined crater, and so on, the character of the crater being always expressed by the number of times the line of least resistance is contained in the diameter of the crater.

Previously to the experiments of Belidor on the effects of charges of mines, it was generally assumed that no crater could be formed the diameter of which exceeded twice the line of least resistance. It was evident that charges might be so small as to produce little or no effect on the surface; on the other hand, if they were large, the great effect of the explosion would reach the surface of the ground, throw up a certain quantity of earth, and leave a hollow in the form of a cone: it was, also, asserted that there was a certain charge which would produce an excavation, the diameter of which would be double the line of least resistance: if that charge were decreased, a less quantity of earth would be raised; and, if increased, then the earth would be projected higher, but the diameter of the crater would be decreased.

CHARGES FOR TWO-LINED CRATERS, OR COMMON MINES.

The data required for the determination of these charges consist in the form of the crater produced by the explosion, and on the quantity of powder necessary to raise a given quantity of earth and to overcome its tenacity.

Form of Crater.—Various figures have been assigned to the solids raised by the explosion of a common mine. Vauban considered it as a cone the vertex of which was placed in the centre of the charge, and found its volume $1{\cdot}05\ l^3$.

Mesgrigny adopted the truncated cone. Le Febvre admitted the cone of Vauban, but added $\frac{1}{7}$ to its volume, which became, therefore, $1{\cdot}20\ l^3$.

Vallière considered it as a paraboloid, having for its focus the centre of the charge, and computed its volume $1{\cdot}90\ l^3$.

Müller truncated the paraboloid of Vallière by a plane passing through its focus perpendicular to the line of least resistance, and found its volume $1{\cdot}84\ l^3$.

The form, however, now generally received by miners is that of a truncated cone of which the height of the axis and the radius of the upper or larger circle are each equal to the line of least resistance, and the radius of the lower or smaller circle equal to half that line: its volume then will be represented by $\frac{11}{6}\ l^3$.

But whichever of these forms be taken as representing the solid in question, it will be seen that the formulæ representing their volumes do not differ very materially.

The cone of Vauban gives too small a déblai. The paraboloid of Vallière exceeds in volume that of the truncated cone by $\frac{1}{29}$ of the bulk of the latter; while, if the figure of Müller be taken, the excess is only $\frac{1}{276}$ that of the cone, a quantity quite unimportant. The result, then, arising from this similarity in the formulæ, is, that the rule for ascertaining this part of the calculation remains nearly equal.

The next step in the computation is to determine the quantity of powder necessary to raise a given volume of the earth, as for example, a cubic yard. This quantity will vary according to the weight and tenacity of the soil; but when ascertained by

experiment, the rule for determining the charge is obvious, viz. to take $\frac{11}{8}$ of the cube of the line of least resistance for the volume; then multiply the result so obtained (reduced to cubic yards) by the quantity of powder required to raise one cubic yard. This latter quantity being, under different circumstances of soil, variable, the results are also variable. But in ground of ordinary weight and tenacity, it has been found, that by taking $\frac{1}{10}$ of the cube of the line of least resistance in feet, the proper charge of powder for common mines is given in ℔s.

CHARGES FOR SURCHARGED MINES, OR GLOBES OF COMPRESSION.

The celebrated French Engineer, Belidor, was the first who employed larger charges than those of common mines, for the purpose of destroying the galleries of the besieger at distances much greater than had previously been supposed possible, and these he called 'Globes of Compression.' Being a Professor in the School of Artillery at La Fère, he had opportunities of making experiments in mining operations, many of which he has recorded.

In 1725 he fired some charges varying from 300 to 3600 ℔s.: in 1732 he fired a charge of 1200 ℔s.: at Bizi, near Vernon sur Seine, in 1753, at his suggestion, a mine charged with 3000 ℔s. was fired by order of Louis XV.; and at Verdun, in 1759, a charge of 4000 ℔s. was fired under his direction. It is said that he caused three mines, each charged with 3600 ℔s., to be exploded at an equal depth of 12 feet, all of which produced the same effect, viz. craters of 36 feet radius; but there is no record of the date and place of making these experiments. At the siege of Schweidnitz by Frederick the Great, in 1762, where Major Le Febvre, a Prussian Engineer, was the Director of the operations, three large mines were exploded, the greatest charge being upwards of 5000 ℔s.

The rules for determining the charges for globes of compression, or surcharged mines, as given by different authors, vary exceedingly.* Belidor considered these charges to be in the ratio of the cubes of the radii of explosion; the rule of General Marescot is to multiply the square of the radii of the craters by the radii of explosion, and then the charges will be in proportion to the products; the rule proposed by Gumpertz and Lebrun accords very nearly with that of Marescot. These authors maintain, that because a certain charge of powder, 3660 ℔s., with a line of least resistance of 12 feet, produced a 6-lined crater, and because this same charge, placed at the depth of 33 feet, will only produce a 2-lined crater, the same relation will hold good in all other mines: therefore, to find the charge of a 6-lined crater, under any assumed line of least resistance a, the proportion would be $12 : a :: 33 : x$; x representing the line of least resistance of a common mine, the charge of which will produce a 6-lined crater with a line of least resistance a.

It is stated, also, that the lines of least resistance of other surcharged mines are determined from the above proportion.

The rules of Major-Gen. Pasley, as given in the following Table, are very valuable, having been deduced from experiments carefully made:

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* See 'Papers connected with the Duties of the Corps of Royal Engineers,' vol. ii. page 20.

CHARGES, AND EFFECTS PRODUCED IN MIXED EARTH.

To find the quantity of powder,	Multiply by	Gives the powder in lbs. to produce No. of lined crater.	Earth thrown out in depth.	Earth affected in depth.	Distance earth or stone is thrown.	REMARKS.
					yards.	
L.L.R.^{3}	$\frac{1}{30}$	1-lined	not defined	..	..	The experiments from which these rules were deduced were carried on in a soil weighing from 90 to 122 lbs. the foot cube, and on a L.L.R. of 6 feet.
,,	$\frac{1}{20}$	$1\frac{1}{2}$-lined	do.	..	..	
,,	$\frac{1}{10}$	2-lined	do.	..	..	
,,	$\frac{1}{4}$	3-lined	do.	..	..	In not attempting to produce more than 3-lined craters, the charges are nearly certain; in surcharged mines, they are not so certain: it is, therefore, better to use a number of small charges to produce a certain effect, than to use one large one; the latter being very wasteful of gunpowder.
,,	,,	4-lined	L.L.R.	$1\frac{2}{3}$ L.L.R.	..	
,,	$2\frac{1}{2}$	5-lined	$1\frac{1}{4}$ L.L.R.	2 L.L.R.	180	
,,	4	6-lined	$1\frac{1}{2}$ L.L.R.	2 L.L.R.	270	
,,	$8\frac{1}{2}$	7-lined	..	..	..	In earth, try to produce 3-lined craters at 2-line intervals, and never with a L.L.R. less than 6 feet.
,,	$9\frac{1}{4}$	$7\frac{1}{2}$-lined	$1\frac{5}{8}$ L.L.R.	$2\frac{1}{2}$ L.L.R.	600	

The rule given in Captain Macaulay's 'Treatise on Field Fortification' is the same in principle as that of Gumpertz and Lebrun, but it is based on a different experiment. It is considered that it may be safely adopted in computing the charges for surcharged mines.

The example on which he grounds his rule * is as follows.

One of the globes of compression at the siege of Schweidnitz was charged with 5404 lbs. of powder, which, being placed under a line of least resistance of 16 feet, produced a crater of $41\frac{1}{2}$ feet radius.

Let it be assumed that the above globe of compression was exploded in common earth; and let it also be ascertained under what line of least resistance the same charge of 5404 lbs. must be placed so as to produce the effect of a common mine, viz. a crater with a radius equal to the length of the line of least resistance. Now as the charges of common mines are in the ratio of the cubes of their lines of least resistance, the following proportion will be obtained, viz.

$$\overset{\text{lbs.}}{100} : 10^3 :: \overset{\text{lbs.}}{5404} : 54040;$$

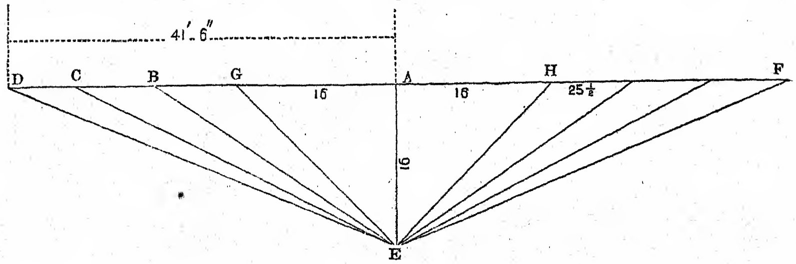
and, extracting the root, 37·81 or 37 feet 10 inches is found to be the line of least resistance required.

It will be observed that, in the present example, the charges have been taken as $\frac{1}{10}$ L.L.R^3, and not as $\frac{1}{9}$ L.L.R^3: the latter co-efficient is used in the computation in Captain Macaulay's treatise.

In the annexed diagrams, D E F, fig. 1, represents the effect of the globe of compression already alluded to as exploded at Schweidnitz, and G E H that of a common mine under the same line of least resistance, the difference, D G, of the radii of the crater being divided into three equal parts: and *g e h*, in fig. 2, also represents the crater of a common mine under a similar line of least resistance, viz. 16 feet; and *d e' f*, fig. 2, the effect of a common mine under a line of least resistance corresponding to

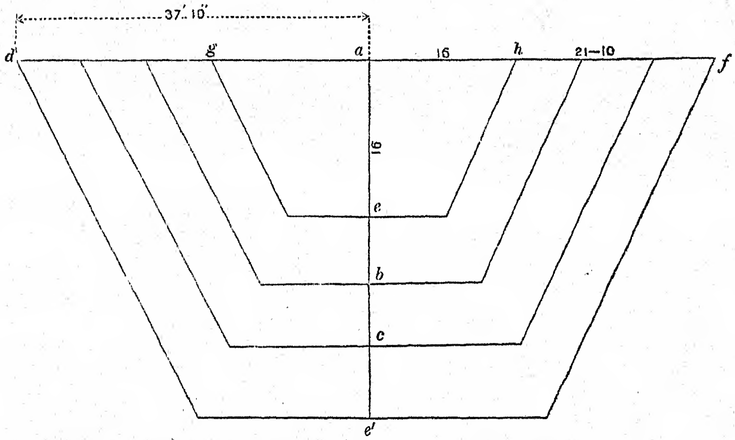
* See page 290 of the Treatise.

Fig. 1.



the charge of 5404 lbs.; the difference, *g d*, fig. 2, between the radii of the two craters being, in like manner, divided into three equal parts.

Fig. 2.



It is evident from a comparison of the diagrams, that if, under a line of least resistance of 16 feet, it is required to produce craters of the radii A B, A C, the charges must be the equivalents of those of common mines with lines of least resistance equal to *a b* and *a c*. From the above reasoning it therefore follows, that a rule for finding the charge for the globe of compression may be thus determined:

Subtract the given line of least resistance (16 feet) from the radius ($41\frac{1}{2}$ feet) of the required crater of the globe of compression, and also from the line of least resistance (37 feet 10 inches) of the common mine requiring the same charge; divide the latter difference by the former, viz.

$$\frac{21 \text{ feet } 10 \text{ inches}}{25 \text{ feet } 6 \text{ inches}} = \frac{21{\cdot}83}{25{\cdot}5} = {\cdot}85\,;$$

then it becomes clear from the diagrams, that if the difference of the given line of least resistance, and the radius of the crater of the surcharged mine, be multiplied by the result of the foregoing division, and that product added to the line of least resistance, the sum gives the required line of least resistance by which to compute the charge.

The general rule, therefore, is to subtract the given line of least resistance from the radius of the crater to be produced; multiply that difference by ·85; add the product

to the given line of least resistance, and the result gives the line of least resistance of a common mine requiring the same charge as the globe of compression.

TAMPING MINES.

The tamping of mines consists in filling up the gallery with solid material for a certain distance from the chamber, with the view of preventing the force of the explosion from expending itself in the gallery, rather than in the direction in which the mine is required to act.

The tamping should extend from the charge for a distance equal at least to $1\frac{1}{2}$ times the line of least resistance; and if the material used for forming the tamping be not heavy, or otherwise but loosely packed, this distance should be double of that line.

The materials usually employed in tamping consist of earth which has been excavated in the formation of the gallery, sods, sand-bags, or indeed of any heavy substance which may be at hand. If the soil be argillaceous, it may be roughly moulded into bricks,* which form an excellent material, and one with which the operation proceeds quickly. The most expeditious mode of tamping is, however, generally considered to be with sand-bags.

Split or cleft timber, in lengths of 4 or 5 feet, and of about 9 inches girt, jammed together in the gallery, is also very applicable, and when mixed with common earth at intervals of 10 or 12 feet, forms a good tamping. Indeed, in the demolition of revetments, by an arrangement of mines in an escarp gallery, it would be found sufficient if both extremities of the gallery were tamped with cleft timber.

In tamping wholly with common earth it is desirable to strengthen the mass by pieces of scantling crossing each other, and placed diagonally in the gallery. These pieces of scantling must be secured in their position by letting their ends into the sides of the gallery, or simply by jamming them.

In a permanent system of countermines it is usual to leave grooves in the walls of the galleries, for the purpose of receiving the ends of the scantling above alluded to.

In a common gallery ($4\frac{1}{2}$ by 3 feet), the tamping, when executed with common earth and well rammed, will not be completed at a greater rate than from 2 to 3 feet per hour.

In proportion as the charge is increased, the value of the tamping diminishes. Experiments were made by Mouzé with the purpose of determining in what ratio the charge must be increased to produce the same effect with a diminished tamping; and he concluded that when the tamping is diminished by $\frac{1}{3}$, the charge should be increased $\frac{1}{4}$; when the tamping is diminished by $\frac{2}{3}$, the charge should be increased by $\frac{1}{2}$; and when the mine is not tamped, the charge should be doubled.

It is often desirable to know the volume of a cubical or other shaped box which shall be capable of containing a given quantity of powder.

In order to this solution, it is only necessary to bear in mind that a pound of powder occupies ~~contains~~ 30 cubic inches, a number from its peculiarity easy to remember, and from which the required size of the box to contain a given quantity of powder can at once be determined.

FIRING MINES.

Mines are usually fired, or, as it is technically termed, sprung, by a powder-hose, or by Bickford's fuze.

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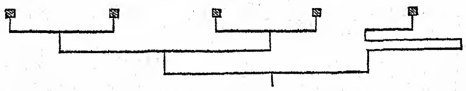
* In some mining operations carried on at Coblentz, by the Prussian Engineers, this mode of tamping was usually employed. In the mining operations executed at Chatham, in August, 1848, the tamping seems to have been composed of walls formed of such bricks, and 3 or 4 feet thick, the intervals being filled with common earth.—J. W.

The powder-hose consists of a tube of strong linen, reaching from the chamber to the outside of the tamping. To protect the hose, it is enclosed in a hollow wooden case represented in profile as follows:  the exterior dimensions of the case being 3 inches, and the interior $1\frac{1}{2}$ inch. The case is fastened to the side of the shaft or gallery by wooden pegs; and in galleries and branches, after it has been secured, it is usually covered with earth, to prevent accidents during the operation of tamping. The mine is fired by a piece of port-fire inserted into the end of the powder-hose, of such length as will give time to the man who fires it to escape before the explosion takes place. The port-fire is then covered all round with moist clay, well kneaded with the hands; and earth is applied round all, so as to render it impossible for any fire to communicate with the powder-hose till the port-fire shall have burnt out.

When it is desired that several mines should explode simultaneously, being fired from one point, it is necessary that equal lengths of powder-hose should extend from the focus or point of ignition to all the mines.



Mode of arranging the hose for simultaneous explosions.

To effect this object, the hose of the mines nearer to the focus must be bent more frequently than those leading to the more distant ones, as in the annexed diagram. The bendings of the hose hasten the progress of ignition, but only in a very small degree,—so small as to be safely neglected.

Bickford's fuze consists of a train of gunpowder enveloped in the strands of a rope which has been steeped in a peculiar composition, and the rope protected by a coat of pitch: it is not injured by damp, and will burn under water; it burns at the rate of 12 feet in five minutes. This fuze is very generally used at Chatham: the French employ a very similar fuze introduced by Captain La Rivière, of the French Artillery.

The Voltaic battery is a means which may be resorted to for igniting mines; but the care and attention required to isolate the wires, and the difficulty of arranging securely so great a length of them, render this application of the battery, however desirable, hardly available for military purposes.*

The rocket is also employed to fire the charge. Like the powder-hose, it requires a case or hose-trough. Wherever a change of direction takes place in the case, care must be taken that it is not made too quickly. At each angle it is usual to place a fresh rocket, with its quick-match secured round a nail: the first rocket, arriving at the point where the second is placed, fires it. In order better to insure the first rocket firing the second, a quantity of powder should be strewed about the match of the latter, protected by a triangular slip of deal, nailed to the bottom of the trough: the first rocket then ignites the powder, and so fires the second, which its rapid motion might otherwise fail to do.

PART IV.—SYSTEM OF COUNTER OR DEFENSIVE MINES.†

In the language of Fortification, the term Mine applies to every subterranean defence;‡ and in *a system of countermines* is included the assemblage of galleries,

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* See the article 'Voltaic Battery.' † By Captain J. Williams, R. E.

‡ "On appelle mines en général, tout chemin practiqué sous terre."—Bousmard, tome ii. p. 88.

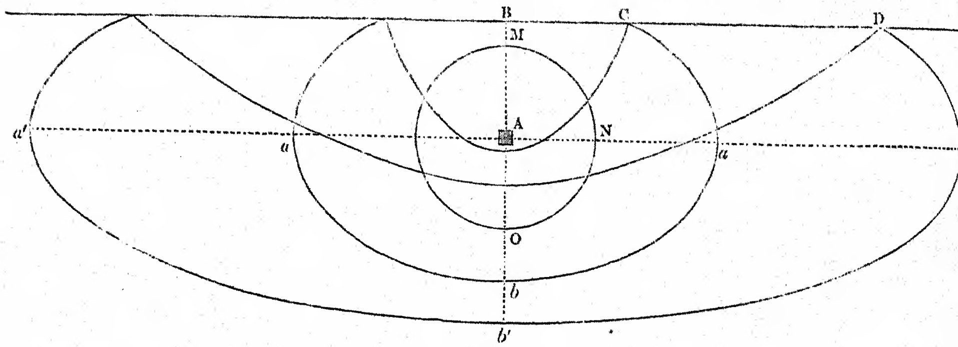
branches, and chambers, placed under the glacis, or under other parts of a fortification, with the view of augmenting its strength.

Previously to describing a system of Counter or Defensive Mines, the effect of an explosion of gunpowder under-ground should be explained, as the results therefrom form the data on which such systems are principally founded.

If a charge of powder, A, fig. 1, be placed at a certain distance, B A, below the surface of the ground in a homogeneous soil, and feebly charged, its effect, when exploded, will be to produce a spherical compression, M, N, O, of the earth, whose radius is smaller in proportion as the charge is reduced.* This sphere of rupture, M, N, O, is, in the language of miners, termed a 'camouflet.'

If the charge be augmented, a crater will be produced; and, under this supposition, the elastic fluid, generated by the explosion, finding a less resistance to its expansion in a vertical direction than in a subvertical, or downward and lateral, the solid of rupture, or, in other words, the distance from the charge to where the soil is pulverized and the galleries destroyed, is no longer a spheroid, but an ellipsoid, or at least some analogous solid.

Fig. 1.



As has been already stated in the article 'Charges of Mines,' the mine is called an ordinary or common mine when the radius B C of the crater is equal to the line of least resistance B A: it is said to be surcharged when the radius B D of the crater is greater than the line of least resistance. It is not practicable to form a crater whose radius exceeds three times the line of least resistance, but the power of producing an interior effect appears without limit.

In the ellipsoid of rupture produced by the explosion of a common mine, unity representing the line of least resistance B A, then the terms for the semi-axes are, $A\,a = 1{\cdot}7$, and $A\,b = 1{\cdot}3$.

For a mine with a maximum charge, or one where the radius B D of the crater is three times B A, it is found $A\,a = 4{\cdot}36$, and $A\,b = 1{\cdot}40$; that is to say, the semi-major axis of the ellipsoid of rupture is about four times the line of least resistance, while the semi-minor axis is represented by $1\frac{1}{2}$ times that line.

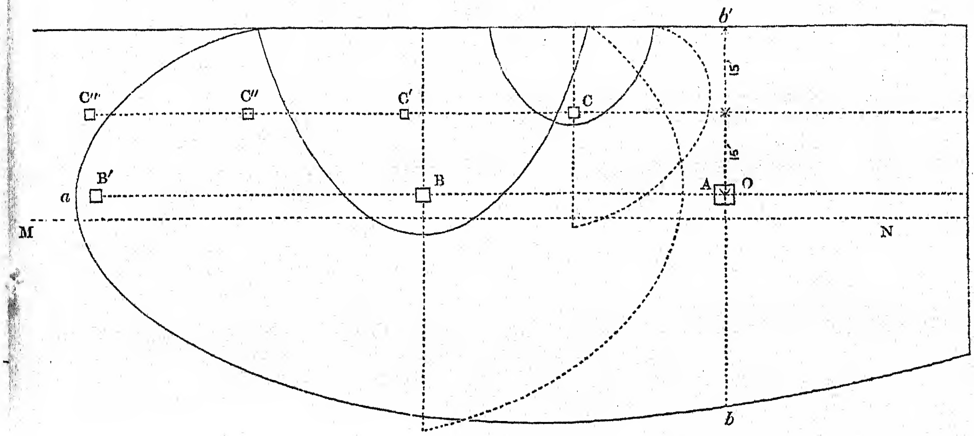
It thus appears, that by increasing the charge, the effects *below* the mine are but slightly augmented; but *laterally* the mine ranges considerably further.

Let now M, N, fig. 2, represent the water level, and B, B′ two mines placed as low as practicable as regards the water level, which mines are supposed to be 30 feet

* See 'De la Fortification Permanente,' by Dufour, page 151.

below the surface of the ground; let C, C′, C″, C‴ be the position of defensive mines placed at half the depth of the first mines B, B′, and, like them, separated from each other by intervals equal to twice the line of their least resistance.

Fig. 2.



The besieger, in driving his gallery as low as possible, would place his mines as near as he deemed prudent to the defensive mines B and C, and load them as Globes of Compression, or Surcharged Mines. The solids of rupture of the defensive mines B and C are represented in figure 2 by dotted ellipses.

It will be observed that they keep off the besieger's third parallel equally distant from the covered-way, when the most advanced mine (C) of the upper system is carried forward a few yards in front of the most advanced mine (B) of the lower system. The besieger's miner then, endeavouring to give to his offensive mine (A) the greatest possible destructive action, would load it with 6000 or 7000 ℔s. of powder, which would give to its horizontal radius of rupture a value equal to four times the line of least resistance, while the vertical radius of rupture would somewhat exceed that line.

But as in ordinary or common mines the semi-axes major of the ellipsoid of rupture may be practically taken at about $1\frac{1}{2}$ times the line of least resistance, it follows from the figure, that from B′ to O the distance is about $3\frac{1}{2}$ times the line of least resistance; and that, consequently, the second mine B′, as well as the first mine B, would be destroyed by the same explosion.

In regard to the upper system of mines, there will be three of them within the circle of destruction of the mine A; the fourth, C‴, being exterior to the ellipsoid of rupture, might be shaken, but would not be destroyed. Therefore, by the explosion of the besieger's globe A, supposing all the defensive mines shewn in the figure to be charged, the two inferior ones, B, B′, containing each 2700 ℔s.* of powder, will occasion a loss of 5400 ℔s. to the besieged; while the four higher mines, C, C′, C″, C‴, containing only 337 ℔s., would entail only a loss of 1001 ℔s. If also the extra tamping be taken into account, as well as the framing for the galleries, which is necessarily more considerable in two large than in three small ones, it will

* One-tenth of the cube of the line of least resistance in feet.—J. W.

be found that the same explosion of the besieger will cause to the besieged, when his mines are established deep, a loss at least fivefold greater than what he would have suffered if his chambers had been placed at one-half of the same depth. Thus, therefore, under the inevitable losses which the besieged must necessarily experience, the defensive disposition C, C′, C″, C‴ appears to have obvious advantages over that offered by B, B′.

On the other hand, the mine C, from its downward or subvertical action, will prevent the besieger from passing below it, and equally prevent him from advancing beyond the line *b b′* as the mine B does: both mines B and C would reach the enemy, if he passed the line *b b′*, with this difference, however, that the mine C would employ—so to say—all its force advantageously at an expense of 337 lbs. of powder to the besieged; while the other mine (B), expending a part of its effort in destroying the tenacity of the ground below, would cause an expenditure of eight times as much powder as mine C. It is from not having considered the effects of mines in a *subvertical* or downward sense, that authors on this subject have fallen into the error now controverted, viz. "That the Besieged ought always to occupy the lowest position for his mines." The superior disposition will require, it is admitted, galleries pushed more in advance, and will cost consequently more, all other conditions remaining the same; but can an expense incurred at the time of the construction of the defensive mines be compared with that which results from a considerable consumption of powder at a period of the siege when it is generally found to be deficient, and when no means can be resorted to for renewing the supply? and, besides, this prolongation of the galleries is not lost to the besieged, since the enemy, who generally is aware of the depth at which the mines are situated, would establish his third parallel at a distance from the crest of the glacis proportionably greater.

If to these advantages, which a system of mines situated at a moderate depth possess, are added those of a readier mode of tamping, of a greater salubrity, by getting rid of the water, and of economy in their first construction,—an economy which is due to the galleries being nearer the surface, and therefore allowing them to be constructed in cuttings, instead of the laborious process of tunnelling,—it will, it is conceived, be conceded that no doubt can exist of the advantages of the two systems, C, C′, C″, C‴, and B, B′ (fig. 2). The upper system will therefore be selected as the most appropriate level for the subterranean defence; and the principle will be assumed, that the chambers of defensive mines should be in the same plane, the depth of which should be from 12 to 18 feet below the surface. The position of the galleries which conduct to them should be in another plane, passing through the bottom of the ditch at the foot of the counterscarp, and rising at such an inclination as to intersect the plane of the mines under the foot of the glacis. The plane of the galleries will therefore be favorably disposed for draining off the water, and keeping the galleries dry.

The mines, disposed as above explained, may be placed in the gallery when the latter is coincident with the plane of the mines; but generally the mines are reached by small galleries driven from the main galleries.

DESCRIPTION OF THE GALLERIES.

After having laid down the foregoing principle, there remains to be given a description of the galleries and branches, and to explain how *they* should be distributed in a work which it is intended to defend by mines.

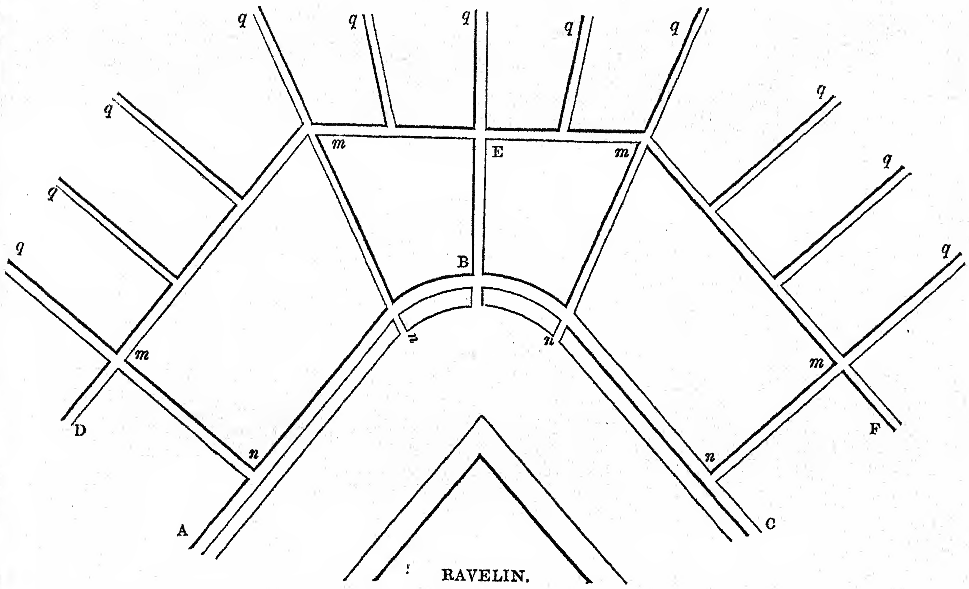
The name of Magistral Gallery is given to the gallery A, B, C, which serves as a

base to the system of defensive mines. The gallery D, E, F, which is parallel, or nearly so, to the Magistral Gallery, and surrounds the work which it is intended to defend, is termed an Envelope Gallery: all the galleries marked *m*, *m*, which lead from the Magistral to the Envelope Gallery, are termed Galleries of Communication; and those marked *q*, *q*, &c., advanced into the country, and presenting their ends to the enemy, are termed Listening Galleries, (fig. 3.)

MAGISTRAL GALLERY.

The Magistral Gallery has occupied different positions in different systems of defensive mines, viz.—under the banquette of the covered-way; under the middle of the terreplein of the covered-way; and, also, immediately behind the counterscarp wall. It is now generally admitted that its best position is immediately in rear of the counterscarp wall: so placed, it has the advantage in economy of masonry; it is better lighted and ventilated, and is less exposed to the destructive effects of the

Fig. 3.



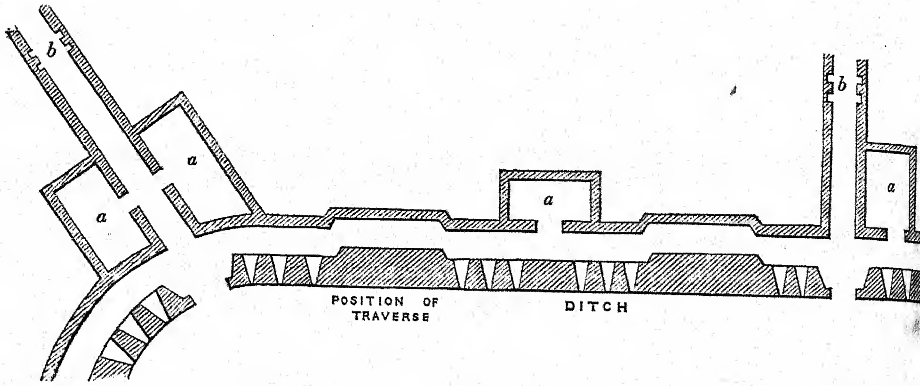
globes of compression employed in the attack. In this position it is termed the Counterscarp Gallery.

The Counterscarp Gallery is not in a straight line, because the thickness of the masonry under the traverses is greater than in the other parts, as shewn in fig. 4.

Wherever the thickness of the wall is diminished, loopholes are pierced in it, which, looking into the ditch, have the advantage of defending it by a reverse fire of musketry, at the same time that they admit light and air into the gallery. The entrances into the counterscarp gallery from the ditch, and which are placed opposite to the galleries of communication, are formed with narrow doors, which doors can be bolted in the inside of the gallery: this arrangement permits the defenders to isolate themselves in the gallery, should the attacker succeed in obtaining mo-

mentary possession of the ditch. Small magazines, marked *a, a, a, a*, (fig. 4,) are constructed as frequently as possible, but principally at the entrances of the galleries of

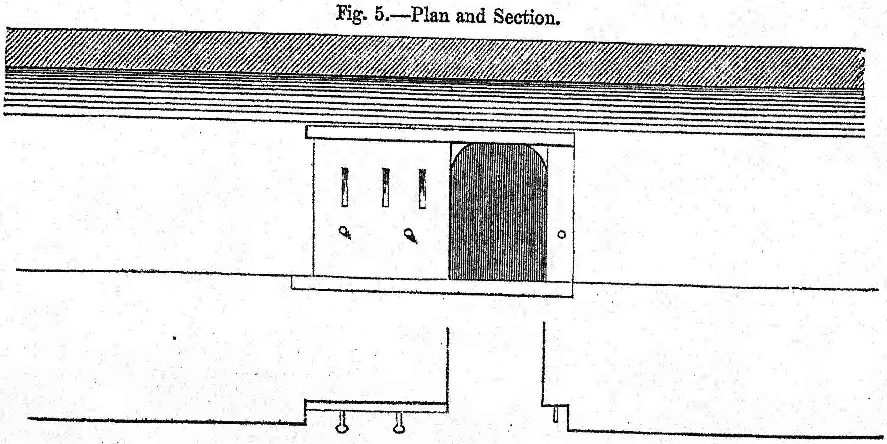
Fig. 4.



communication: these magazines are convenient recesses for holding tools, the framework of galleries, and sand-bags for tamping. The driest and most secure of these small magazines are appropriated for the powder used in the mining operations. Sliding loopholed doors afford means of cutting off the gallery of communication from the counterscarp gallery when the enemy has possessed himself of the former. These doors are covered with plate iron, and are represented in fig. 5. They are moved by two handles, and are fastened by means of iron pins, which pass through the door into the wall.

The Counterscarp Gallery should be 6 feet broad and from 8 to 10 feet high.

Fig. 5.—Plan and Section.



ENVELOPE GALLERY.

An Envelope Gallery has the great defect of presenting its sides to the Globes of Compression of the Besieger, and, from its advanced position, is liable to be easily destroyed. But as it serves as the base of more advanced defensive galleries, it

follows, that all these galleries become useless when the besieger has succeeded in destroying the envelope gallery towards its two extremities. The envelope gallery has, also, the inconvenience of serving as a base to the besieger's miner, after he has gained possession of it. He will push forward his subterranean operations with so much greater facility in working from the envelope gallery, which will contain all the material, &c., necessary for the construction of his galleries. The miners of the besieged and the besieger would then meet on equal terms, which equality is certainly contrary to the spirit of a good defence.

It has also been urged against envelope galleries, that they cannot be enfiladed by the guns of the fortress, and that they serve as a trench to the besieger. But this does not seem a valid objection; for it appears impossible to enfilade a gallery, nor can it be conceived that such gallery, placed at 15 to 18 feet below the ground, could serve the enemy as a trench. However this may be, the objections previously cited are sufficient to condemn envelope galleries, and to abolish them from projects of defensive mines. They ought to be employed only when introduced in small portions. These small portions of envelope galleries, when it is judged proper to employ them, should be 6 feet high and 4 feet broad.

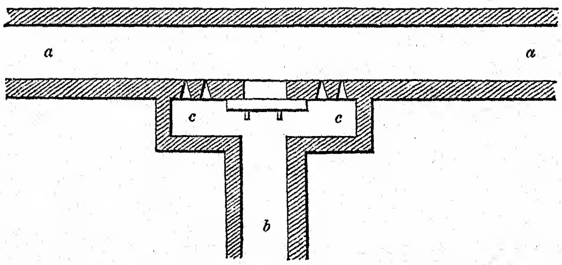
GALLERIES OF COMMUNICATION.

Galleries of Communication exist wherever there are Envelope Galleries, or portions of Envelope Galleries; or otherwise, they extend from the Magistral Gallery to the position occupied by the Envelope Gallery. Their dimensions are the same as those of the envelope gallery, because, like it, they should be adapted to an active circulation, and serve as temporary dépôts for the tools and materials necessary for preparing the mines and for completing the tamping. At certain intervals, grooves, *b, b* (see fig. 4), are left in the brickwork of the galleries generally, in order to have the power of interrupting the communication by a barricade of beams, strengthened with sand-bags, when the besieger's miner has arrived as far as the envelope gallery. These small barricades serve also to increase the effect of the explosion of a mine when circumstances require that it should be hastily sprung.

In case of a sudden irruption of the besieger's miner into the envelope gallery, it would be advisable to have the means of closing the galleries of communication, at their junctions with the envelope galleries, by sliding doors, moveable in the same way as has been described in fig. 5.

In the annexed fig. 6, *a, a* represents the envelope gallery, and *b* the gallery of

Fig. 6.



communication: the recess, *c, c*, is necessary to the working of the sliding door, and would serve as a dépôt for tools so long as the besieged remained master of the

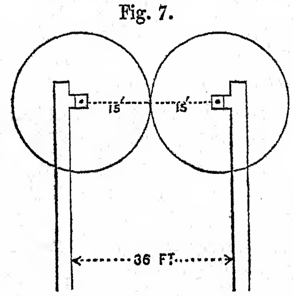
gallery *a, a.* The loopholes on each side of the door would allow of pistols being employed to defend the door.

LISTENING GALLERIES.

It is by means of Listening Galleries, which are pushed forward as far as the foot of the glacis, and sometimes further, that the besieged informs himself of the approach of the attack: placing his ear close to the ground, he hears the sound of the blows of the enemy's tools, judges of the direction of his approach, and commences a small branch to take the miner in flank. It is from these circumstances that these galleries have been termed Listening Galleries.

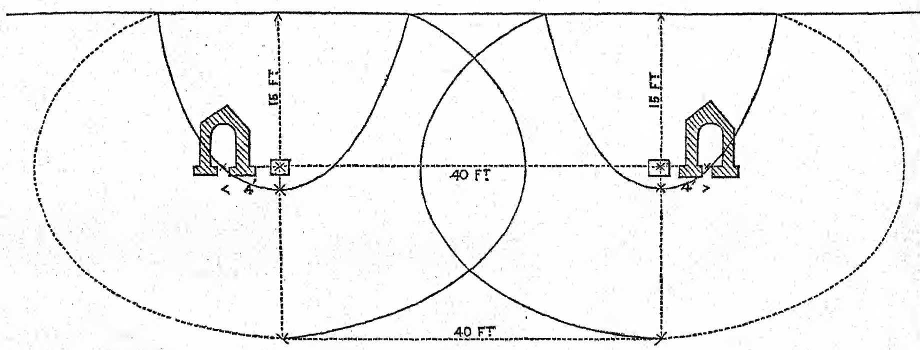
The sound of the enemy's pickaxe can be heard only at a distance of about 60 feet; and for this reason the listening galleries should not be separated by intervals greater than 100 to 120 feet, in order to prevent the besieger's miner passing between them unheard. The distance of 120 feet will then be the maximum distance between the listeners. But these galleries are not only destined to warn the besieged of the enemy's approach, but upon them principally depend the whole of the subterranean defence. If, then, a mine is supposed to be prepared in each of two consecutive listeners, and that these mines have a line of least resistance of 15 feet, they would, when exploded, raise the whole space included between the two listeners, if the latter were separated by 36 feet centre interval.

Fig. 7.



But if it be remembered that the destructive effect of a common mine extends in a horizontal direction $1\frac{1}{2}$ times the line of its least resistance, it is evident that the listeners may be placed at central distances of from 45 to 54 ft., that is, from the centre of one gallery to the centre of the next; and, thus disposed, equally prevent the besieger passing between them. It will be considered, then, as laid down, that with the mean depth of 15 feet, which appears best adapted for defensive mines, two parallel listeners should be placed apart at about central intervals of 48 feet; and, in this position, the following figure (8) shews by a profile how the mines defend the

Fig. 8.



interval, and how deep it would be necessary for the besiegers to go, in order to avoid their effect. The chambers of the mines are at 40 feet intervals, the distance of 48

feet between the listeners being reduced by the length of the two small branches which lead to the mines from the galleries.

Listeners cannot be pushed very far without becoming untenable from bad air. Experience has shewn that the air becomes altogether unfitted for respiration when the head of the gallery has advanced 130 feet. It is necessary that the disposition of defensive mines should be arranged so as to procure currents of air, and that no galleries have a greater length than 120 feet without being crossed by another.

The listeners, presenting their ends to the enemy, are the best disposed to escape, as far as is possible, the destructive effects of globes of compression. Whenever the besieged ascertains that the besieger is preparing a globe of compression, which will be exploded at some distance from the head of his own listeners, he makes use of his most advanced mines in those listeners, not to crush the enemy, who is out of reach of his ordinary mine, but to make a sort of rupture or cut in the soil, so as to deaden the effect of the globe of compression, the force of which would be diminished by acting in a soil already loosened and shaken. Such is the first effort of defensive mines; its purpose is simply to neutralize to a certain extent a blow which menaces them. But after the first globe has been sprung, and after all the evil it can produce has been felt, and when the direction the besieger's miner has taken on leaving the vast crater produced by the globe has been discovered, then the besieged prepares a new mine, either in the listening gallery or in a branch leading out of it; and as this defensive mine in the branch may be exploded before the besieger has prepared his second globe of compression, the garrison take the offensive, and spring this mine, which will perhaps crush the enemy's miner, or at least delay very considerably his operations.

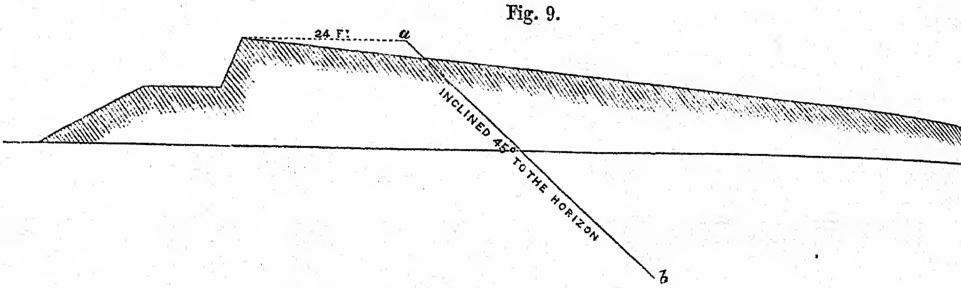
From what has been already stated, it is evident that when a defensive mine is placed behind the masonry of a listener, or at the extremity of a short branch leading from it, the listening gallery itself requires to be tamped: it is necessary, therefore, that it should have such dimensions, that while it admits of a tolerably easy communication, it is not so large as to demand great labour in tamping. In order to fulfil these two conditions, listeners are generally made 3 feet high and 2 feet 6 inches wide.

To facilitate the execution of branches from the listening gallery, openings are left at the time of their construction, at intervals of about 30 feet, in the side walls, having the same dimensions as the branch; and in order to prevent the earth from falling into the gallery through these openings, they are closed by a thin masonry wall, about 4½ inches thick, which can easily be removed when it is required to commence a branch from the gallery. Grooves about 4½ inches deep are also left in the walls of the listener at intervals of 8 or 10 feet from each other: these grooves form a support for beams of timber placed diagonally across the gallery,—an arrangement which strengthens the tamping, and saves time in its execution. This economy of time in the preparation of the mine is to the besieged of the greatest importance, as it will frequently enable him to spring his mine before the besieger is ready with the globe of compression, which would entail the loss of the powder with which the latter was charged, and retard by many days the progress of the subterranean attack. With the same view of the economy of time, the probable position of the chamber of a mine should not be more distant than 12 feet from the nearest listener, from which a branch may be driven in twenty-four hours. The best arrangement would certainly be to dispose the listening galleries so near to each other, that a mine fired from behind the side wall of the listener would destroy the besieger's gallery in whatever position it might be; but such a system of defensive

mines would multiply the number of listeners too largely, and the advantages would not be commensurate with the increased cost of construction.

It must be understood that the besieged may place mines in any position along his galleries, either in the galleries themselves, or in branches leading from them. Care,

Fig. 9.



however, must be taken, in determining the places of those nearest the covered-way, that by their explosion the crest of the glacis is not blown away, and the defenders of the covered-way exposed. The chambers of the mines alluded to, whatever may be their depth, should be in a plane inclined 45° to the horizon, parallel to the crest of the glacis, but passing 24 feet from it; so that, after the explosion, there will remain 24 feet thickness of earth as a parapet to the covered-way.

The mines placed nearest the covered-way are in a plane of which *a b* is the vertical trace.

The mines placed nearest the covered-way are intended to blow up the breaching batteries of the besieger, should he have had the imprudence to construct them without possessing himself of the ground below. Their position being determined, the branches leading to them may be constructed beforehand. It is not usual to establish mines in the covered-way, because the besieger does not usually lodge himself there, and because their explosion would probably facilitate the descent of the ditch.

ARRANGEMENTS ADOPTED AT THE JUNCTION OF GALLERIES TO FACILITATE THE COMMUNICATION AND INCREASE VENTILATION.

At the point of junction of two principal galleries, as that of an envelope with a gallery of communication, it is usual to construct small vaulted chambers, as are
Plate IV. represented in figs. 2, 3, and 5.

These chambers are necessary to facilitate the communication at the junctions; they serve as entrepôts to the miners for their tools and materials; they afford, also, stations for the workmen, who wheel in the earth in barrows, and then fill the sand-bags for tamping. In order to improve the ventilation, the vault is sometimes pierced at the top (communicating with the surface of the ground) by a cylindrical orifice, 3 or 4 inches in diameter (see fig. 2). The chambers are occasionally circular, as shewn in fig. 2; or rectangular, when the galleries cross each other at right angles (fig. 5); or lozenge shape, when the galleries cross each other obliquely. In the first arrangement, the chamber or junction of the galleries is covered by a dome; in the second and third, by groined arches: at any junction containing more than two galleries, the chambers should always be circular.

There is another description of chamber, which is sometimes made in the middle of long galleries, in order to facilitate the communication between them. This chamber (fig. 4) affords all the conveniences of that at the junction of galleries, and

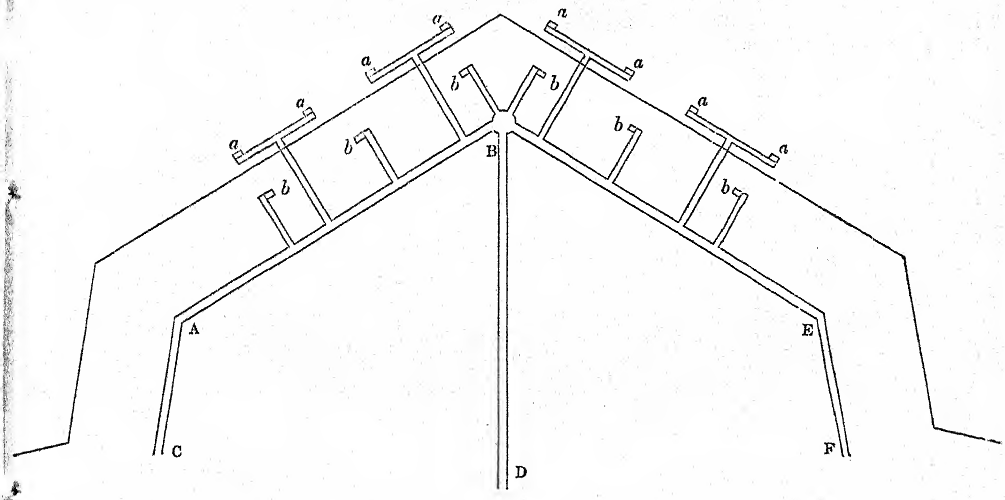
consists simply of an increase in the breadth of the gallery, covered by a cylindrical arch, higher than that of the gallery, but concentric with it: the gallery, at that part of it which forms the chamber, is set back on each side about 2 feet, being a breadth sufficient to allow of the miners with their loads passing each other.

The chamber also affords the means of closing the gallery by a door with one leaf (*a b*, fig. 4) when it is desirable to stop all communication suddenly.

MINES FOR THE DEFENCE OF THE BODY OF THE PLACE.

It is not only under the glacis of the fortress that defensive mines are constructed; employment should also be made of their powerful aid to retard the besieger, giving the assault to, and establishing a lodgement on, the bastions. With this view, a gallery is constructed parallel to the escarp of the face of the bastion, and about 20 yards in rear of it (see fig. 10), communicating with the ditch of the interior retrenchment, or with the interior of the fortress, by means of a gallery on the capital B D, and by two galleries A C, E F, parallel to the flanks. The galleries A B, B E, serve as a base to a system of branches leading to mines *a, a, a, a, b, b, b,* the former being situated under the ruins of the probable position of the breach, and the

Fig. 10.



latter under the lodgements usually made by the besieger on the crest of the breach. The first series of mines are intended to blow away the earth brought down by the fall of the escarp; and as these mines should be a little surcharged, the débris would be projected violently against the besieger's works, and the breach becomes impracticable. The mines *b, b, b,* should be sprung at the moment of assault, in order to bury the besieger amidst its ruins, or to destroy the lodgement which the latter may have succeeded in establishing on the summit of the breach.

The mines *a, a, a, a,* are constructed sufficiently low, while the others, *b, b, b,* are placed at half the height of the revetment. (See profile given in Plate V. fig. 6.)

It is necessary, then, that the escarp gallery A (fig. 6), which represents the profile of the system, should be placed at such a level that it does not require

too quick a descent in order to reach the mine B, placed at the foot of the breach, nor too rapid a rise to gain the mine C. If it be supposed, for example, that the height of the escarp is 30 feet, that the mine C is placed at half that height, that the mine B is 9 feet below the bottom of the ditch, and that the escarp gallery
Plate V. is 20 yards from the back of the revetment, then the floor of the latter gallery ought to be raised about 6 feet above the bottom of the ditch, in order that the branches A B and A C may have slopes of equal inclination.

Fig. 6 also shews the effects of the mines B and C on the ramp of the breach.

A communication is sometimes established between the escarp and counterscarp galleries by means of a passage under the main ditch; but this sort of communication is not convenient, as it can only be entered either by a ladder or a quick ramp: moreover, it is liable to be filled with water, and made impassable.

This arrangement has, however, some advantages, when there is a wish to dispute the descent into the ditch by mining operations; because the gallery in question forms a concealed and covered passage to the scene of the miner's operations. Without this under-ground gallery, it would be necessary, under such circumstances, to cross the main ditch, exposed and unprotected, in order to gain the counterscarp gallery; and, as the besieger occupies the covered-way, this would be a service of great danger. It is, however, to be remarked, that the counterscarp gallery runs throughout the whole extent of the counterscarp, by which means it may be entered at distant points from the front of attack, which in this way may be reached; but besides, as this arrangement renders it necessary for the besieger to make a circuitous route, it is also necessary, in order to guard against surprise, to interrupt the communication, and to cut off the counterscarp gallery towards the flanks or extremities of the front of attack by strong barricades, in order to isolate the part of it attacked. Without such precaution, it might happen that a violent explosion disclosing an opening in the counterscarp gallery, the besieger might enter it in force, spread right and left, and menace with a surprise the different portions of the Body of the Place.

Since, then, the counterscarp gallery does not always give to the besieged a sure route to reach the besieger's miner, when the latter is pushing his descent into the ditch, it is evident that there remains no other choice for the former than to cross the ditch, exposed to view from the besieger's lodgement, or else to employ the subterranean gallery already alluded to. When it is decided to construct such a communication, it is necessary to add a cesspool in the centre, and to arrange the floor of the gallery so as to drain into it the water that collects on its surface.

In case the galleries of mines cannot be drained into the ditch of the main work, recourse must be had to similar cesspools.

The dimensions of a gallery below the level of the ditch are the same as those of an ordinary gallery of communication, which is usually 6 feet high by 4 feet broad. But its masonry should be a little stronger than that of an ordinary gallery, because, having from its position but a slight covering of earth, it is liable to be crushed
Plate IV. by shells: it is therefore usual to give it a thickness of about 2 feet. Fig. 5 shews that grooves are made in the masonry immediately behind the cesspool; by the assistance of which, barricades could more easily be made in the gallery, which would intercept all communication when it is decided finally to abandon the mining operations under the covered-way.

The names, dimensions, and positions of the various galleries having been now explained, it becomes necessary to describe the trace of a simple System of Defensive Mines, viz. that proposed by Dufour. (See Plates II. and III.)

If the fortification have ravelins with considerable saliency, as in the French Modern Bastion System, it will be inexpedient to place mines under the glacis opposite the salients of the bastion. For it results from the march of the attack, that the besieger gains possession of the ravelin previous to pushing forward his approaches on the glacis opposite the bastion; and therefore, as the passage of the main ditch is exposed to the view of the besieger's lodgements in the ravelin, the garrison could not communicate with the mines under the glacis of the bastion, excepting by a subterranean gallery below the ditch,—a mode which, as has been already stated, is often rendered impracticable from the difficulty of drainage, and is always insecure and uncertain. Besides, too, after the besieged have carried on for some time an active defensive subterranean warfare under the salient portions of their defences, it is not likely that the provision, either of powder or of men, would allow them to renew the struggle in the re-entering portions opposite the bastions.

The system of defensive mines here proposed must, therefore, be considered as applied only to the salient portions of the trace: but it must be understood, that where the besieger could crown the covered-way of the ravelin and of the bastion at the same time, a similar disposition of defensive mines must continue along the whole contour of the glacis. Making the pan-coupé of the salient place of arms 9 yards in length, lines *p q*, *q r*, *r s*, are drawn parallel to the crest of the glacis, and 60 yards from it. These lines give the limit of the extreme points of the galleries. Parallel to *q r*, and 72 yards from it, a gallery, *t r*, is made at right angles to the capital, and extending 20 yards on each side of it. Each end of this gallery is joined to the points *q* and *r* by two galleries, *q t*, *r v*, and the latter are produced to the counterscarp gallery. They are connected by a transverse gallery half-way between the lines *q r* and *t v*, and parallel to them. A gallery on the capital extends from *q r* to the counterscarp gallery, and, half-way between it and those terminating at *q* and *r*, are two others, extending only as far as the outer transverse one. The position of the galleries on each side is determined by placing the extreme points at equal distances of 26 yards apart, commencing from the points *q* and *r*. The first two are directed to the points *t* and *r*, and the remainder are parallel to them.

In this system the chambers of the mines and the floors of the galleries are in two different planes, which intersect at the extremities of the galleries. The plane containing the floors of the galleries, fig. 1, inclines towards the ditch, till it terminates in the counterscarp gallery: this inclination facilitates the drainage: the plane of the chambers of the mines inclines upwards, terminating at its intersection with a plane inclined to the horizon at an angle of 45°, and passing 8 yards from the crest of the glacis. The nearest mines to the fortress being at this intersection, will prevent the possibility of the besieged destroying the parapet of their own covered-way. The galleries are just near enough to insure the besieger's miner being heard, if he attempts to pass between them, but too far to insure his being destroyed in them by the explosion of common mines. The position of the mine chambers is, therefore, reached by means of short branches, constructed for the purpose when the besieger's miner is heard at work. To facilitate this operation, openings *a*, *a*, *a*, *a*, fig. 1, large enough to commence branches from, are left in the revetment of the galleries, and parts even of the branches may be constructed permanently, in order to save time when the attack is made. At the junction of the galleries, the arrangements already described for increasing the ventilation and facilitating the communication would be made.

Plate IV.

PART V.—ATTACK AND DEFENCE OF A SYSTEM OF COUNTERMINES.*

SECTION I.—OPERATIONS OF THE BESIEGER WHEN HE ARRIVES IN THE VICINITY OF COUNTERMINES — SUBTERRANEAN COMBATS BETWEEN THE RIVAL MINERS.

When the besieger arrives in the vicinity of the glacis of a countermined fortress, he is obliged to move more slowly, and dares not advance on the surface of the ground further than what he may be master of below. He then commences to excavate the earth, in order to try to discover the galleries of the besieged, and seize them, or else he endeavours to blow them in by firing mines. To accomplish this, in the middle of his third parallel he sinks shafts such as *a*, fig. 1, from 16 to 21 feet deep: he then pushes forward a gallery *d*, taking care to stop working at intervals, to listen if the enemy is coming to meet him.

Plate VI.

Often the besieged, especially when his galleries extend to a great distance, drives a branch almost under the third parallel, and fires one or more mines, such as *c*. The besieger, under this supposition, ought to make a lodgement on the edge of the crater, as shewn in the figure, and sink a shaft (*b*) in his own lodgement. This shaft is not sunk from the bottom of the crater, because it would be the reservoir of all projectiles thrown from the place. Care must be taken, however, at the same time, to clear away the excavation caused by the globe of compression, in order to discover the direction of the branch which joins it, and which necessarily communicates with a main gallery. (See Plate VI.)

While the besieger is sinking the shaft *b*, he ought frequently to listen, for there is not a doubt that he is now in the vicinity of the mines of the besieged; and when he arrives at the depth of 18 or 20 feet, he commences a branch *e*, breaking out on that side where he imagines the enemy's gallery to be situated.

When the besieger finds himself sufficiently near to the Gallery of the Place, and is in danger of being forestalled, he hastens to dig a chamber at the extremity of his branch, in which he places a certain quantity of powder: he then tamps as fast as possible, and endeavours to fire his mine before the besieged can find time to establish one to destroy his work.

The besieged, on their side, directly they cease to hear the sound of the pickaxe, work with the greatest possible diligence, because they suppose from that instant their enemy is engaged in tamping their mine. If they have the good fortune to fall in with the mine, they endeavour to seize the powder, or else to saturate it by an inundation of water. If, on the contrary, they discover a part of the branch already excavated, they ought, without delay, to inundate it, in order to destroy the hose, and so prevent the powder from exploding. These artifices are made use of in like manner by the besieger.

It sometimes happens that two miners, who are working to meet each other, are only separated by a slight partition of earth. This is an occasion seized upon to give the 'camouflet,' which is performed in this manner: the most active of the two pierces a hole on the side of his enemy with borers of different diameter, in order to enlarge it gradually, and to give it a diameter of 6 inches: he digs this hole as deep as he can,—from 6 to 8 feet, for instance: he then introduces a large cartridge of the same size, containing from 12 to 20 ℔s. of powder: he drives in this species of mine with a plug of wood, which he fixes and props up strongly with a piece of wood across the branch: finally, he fires this little mine by means of a fuze which goes through the middle of the plug.

* By Lieut. De Butts, R. E.

If the gallery of the enemy is but 4 or 5 feet from the head of this cartridge, he may be sure that it will be driven in by the explosion.

To produce the same effect, two or three shells, fixed together, are sometimes employed; but this method requires a great deal of care and attention, in order that one's own labour be not exposed to destruction.

In subterranean warfare, when two miners are working to meet each other, they take care to try the ground frequently with a borer, to find out exactly what distance they are off. In such a case, he who sees the end of his enemy's borer appearing, keeps a strict watch on the moment it is drawn back: he then introduces quickly into the hole it leaves a pistol loaded with ball, and fires it the moment he imagines the hole is clear.

This ought to be followed by three or four more; after which a probe is pushed into the opening, to clear it, and prevent the enemy from coming through on that side.

Vauban recommends the following articles to be provided in attacks of this description:

1st. A frame of wood like a shield, 3″ or 4″ thick, with a bolt in the middle to manage it with, and to place it against the hole perforated by the probe.

2ndly. Smoke balls: they are pushed in through the same hole when lighted, and care is taken to stop the orifice on one's own side, so that all the smoke goes into the enemy's gallery, by which means their miner is driven away for some time. During his absence the mine is charged and fired, which, by blowing in the gallery, prevents the return of the enemy. If the opening is wide enough, a shell or portfires to suffocate, or grenades, may be introduced. The shell is to be preferred when it can be used, because it destroys the part of the gallery where it falls. When a thin partition of earth divides the combatants, a petard is used to blow it in.

Such are a great part of the artifices made use of by miners. To avoid them, the besieger should, as soon as he can, fire a mine to blow in the branches, and even the galleries of the besieged, if within reach. He is sure, by this means, of driving him away for some days. It is well known that the firing a mine shakes the ground to a considerable distance, so that if a gallery be within this limit, the gases of the powder penetrate and poison the air with such effect that no one can breathe it. This is not felt so much by the besieger, as he has more air, and is not obliged to use such long galleries.

Notwithstanding all the obstacles opposed to the advance of a besieger, he finally contrives to discover one of the main galleries of the besieged. Sometimes he arrives at it direct by mining: sometimes he gains access by means of the branch of the enemy which he meets in his road. In both cases there are means of attacking and defending a gallery, which will be given in the following section.

SECTION II.—STORMING OF THE GALLERIES—METHOD OF TURNING THE RETRENCHMENTS.

As soon as the besieger has discovered the gallery of the enemy, he ought, without delay, to attack it with vigour. For this purpose he takes care to provide himself with a small rolling mantlet, or shield, 3′ 2″ broad, and 3 feet high at the most. If this machine were larger, it could not pass through the branches. Covered by this mantlet, the miner advances, followed by men armed with grenades, presenting towards the besieged a machine filled with pistol barrels, which keep up an incessant fire. He may also use grenades, or small shells, which are carried in a barrow, or other machine, behind which the miner covers himself. If by these different

manœuvres he manages to penetrate to the retrenchments of the besieged, he endeavours to break it in, close with the enemy, and drive him back as far as possible by means of halberts, bayonets, and pistol-shots: after this, he barricades the abandoned gallery, or else makes a lodgement with sand-bags.

The besieged, on their side, have different methods of intrenching themselves in their galleries. When they are in brick-work, care is taken to divide them Plate VI. beforehand, every 30 yards or so, by oak doors B and C (fig. 2). These doors are pierced with a large loophole, which is shut by a spring shutter. Inside and outside the door, blind branches (*d, d*) are made in the footings of the gallery, one to the right, the other on the left. The following is the object of this disposition.

Let us suppose the gallery B C to be an envelope gallery into which the enemy have penetrated by the branch A. The defenders then retire behind the doors B and C, which are closed in such a manner that they can be barricaded on both sides: the spring shutter is opened, and through the loophole are thrown small leather sacks filled with fireworks and furnished with a lighted piece of tow; grenades are also thrown into the abandoned part of the gallery. The burning and explosion of the powder enclosed in these different projectiles cause such a smoke that the besieger cannot support it. By repeating this manœuvre, sufficient time is gained to bore, with a borer 6 or 7 inches in diameter, a hole in which from 24 to 30 lbs. of powder are placed, which is tamped properly. The explosion of these small mines (*f, f*) will not fail to bring down the walls on the side of the besieger, and thus form in front of the gates a solid barrier, nearly inacessible on account of the noxious vapours which generally exhale from earth and ruins impregnated with the smell of the powder.

If the besieger observes that the gallery has a sensible slope towards one of the doors, towards B, for example, he ought to close it up with sand-bags, as shewn at D, in order to prevent any return of hostilities from that side: then, taking advantage of the slope to B, he will roll down howitzer shells, which, bursting near the lower gate, will break it in. The besieged is thus obliged to retire 30 yards further. If the slope were sufficient for a strong man to roll the shells right up to the next gate, the besieged might thus be forced to abandon 80 or 100 yards of gallery without risk to the besieger, and to which the besieged could not return if care were taken to burn at intervals bags of powder.

It may, however, happen that the besieged are so strongly retrenched, and have so well known how to employ their means of defence, that the besieger is Plate VI. fig. 2. obliged to give up the hope of penetrating by the branch A. In this case a great deal of confusion may be caused in the enemy's gallery, and all the barricades broken down by rolling against them one or two barrels of powder, having a lighted match attached. But if B C form part of an envelope or of any other gallery of great length, and in a straight line, there is another mode of attacking and turning the retrenchments, both easy and expeditious; and which may be thus explained.

The besieging miner closes instantly the opening G with sand-bags, which he makes secure by filling up the spaces between the bags with clay, well rammed in. This done, he works without ceasing at the excavation of branches, 5 or 6 yards long, by the side of the foundations of the gallery. At the extremities, holes are driven with a borer from the top of the branches to the surface of the ground. The ends of the borer shew on the surface (of the ground) two points which will be of service in discovering the direction of the long gallery.

Let us suppose that by this means the position of the gallery A B (fig. 3) has been

discovered: a flying sap is thrown up as far as B the following night, above ground, and a shaft sunk on the gallery, 10 or 12 feet deep, in which a mine containing from 110 to 170 lbs. of powder is placed. The firing of this will infallibly break through the gallery, and by this speedy and certain manœuvre the besieged is forced to abandon a great part of his subterranean works.

There is another mode of attack which has not been used up to the present day, and which might nevertheless prove an infallible means of reducing, in a short time and with little danger, a system of defensive mines.

Let us suppose that a subterranean warfare has to be carried on in front of a fortress where there is a lake, a stream, or other source of water: if the ground on which the attack is made is not much above the level of this water, there would be no difficulty in raising it by means of pumps, which might be worked by machines or by water-wheels, which are frequently met with by the side of running waters: the water thus raised might be poured in torrents into the galleries of the besieged directly a passage into them is made. By this means a great part of the defensive mines might be inundated to such an extent as would render them perfectly useless, or at least facilitate greatly the attack.

All the operations herein described are slow, and the success of some of them uncertain. To shorten the work, the besieger sometimes takes the opportunity of attacking the counterscarp with a body of men: for this purpose a great number of grenadiers, sappers and miners, are collected in the third parallel: these troops rush out before day-break, and force the barriers and palisades of the covered-way. Immediately after, a detachment of miners, supported by grenadiers, descend into the ditch and endeavour to penetrate the galleries of the besieged by the entrances which are usually placed at the roundings of the counterscarp. They tear away the hoses of the mine already charged, try to pull down the frames of the galleries made of wood, and if they find a powder magazine of the enemy, they take one or two barrels, which they roll to the diverging points of the main galleries; they place a match in them, and retire. The explosion of this powder, which is not strong enough to displace the earth above, causes a great disorder in the galleries, and is sufficient to prevent the besieged from re-entering there. Such a sudden attack, if it succeeds, may doubtless give a great deal of time to the besiegers. It must, however, be admitted that such an attack would be rash, and it must be premised that a weak or badly commanded garrison has to be dealt with.

Such was the method of attack and defence as recorded in the two previous sections, before the discoveries of Belidor on the effects of globes of compression.

SECTION III. — ATTACK OF DEFENSIVE MINES BY GLOBES OF COMPRESSION — CALCULATION OF THE TIME REQUIRED TO REDUCE A SYSTEM OF MINES BY THIS MEANS OF ATTACK.

Belidor, reflecting on the effects of powder, suspected with reason that the gases which result from its explosion ought to act in the same manner as all elastic fluids, which tend to displace obstacles in every direction opposed to their dilatation; and as the volume of the gas is so much greater as the quantity of powder enclosed in the mine is more considerable, he concluded that under the same line of least resistance the craters ought to increase with the charges. Further on is given the result of the principal experiments by which he supported his theory, and on which he founded his method of attacking defensive mines.

The first experiment which he made was at La Fère in 1739. The mine N

Plate VII. (figs. 3 and 4), having a line of least resistance of 10 feet, was placed 25 feet from the gallery C D, 30 feet from D E, and 35 feet from E F, and finally 42 feet from F C. There was, besides, an inclined branch T, whose top, B, was 13 feet below the gallery. (See fig. 4, Plate VII.)

The mine was charged with 1200 lbs. of powder, and on firing it all the galleries were driven in, nearly in inverse ratio of their distance from the mine, as shewn in fig. 3. The branch which was under the mine was likewise driven in, and the diameter of the crater was found to be 45 feet.

This experiment, although conclusive in its results, did not convince some miners, which caused Belidor to propose new proofs. The French Government, feeling the importance of such a discovery, granted his request; and Count Argenson, then Minister of War, assembled Belidor and several officers of Artillery and Miners at Bizi in Normandy, where, in the grounds of the Duke of Belleisle, he caused the following experiment to be made.

In ground composed of soft sandy stone, four galleries, A, B, C, D, were built in Plate VII. masonry (figs. 5 and 6). The mine F, having a line of least resistance equal to 12 feet, was placed 24 feet from the gallery C, 30 from A, 36 from D, and 42 from B. Under the mine was a gallery lined with stout oak casing, 14 feet from the charge.

The charge was 3000 lbs., and the explosion produced a volcano nearly 150 feet high: the crater, 66 feet in diameter and 17 in depth, was perfectly circular.

The galleries D and A were broken in the whole of their length, except about 12 feet at one of the ends.

The gallery C was destroyed for the length of 45 feet, so that at one end 16 feet, and at the other 12 feet, were left standing.

Finally, the gallery B was entirely broken in, with the exception of 12 feet at the end the most remote from the mine.

The gallery under the mine was found to be destroyed to the length of 12 feet, which leaves for the hypothenuse of the triangle E F Z (fig. 7) only 38 feet. From this Belidor concluded that his globe would have destroyed a gallery 50 feet under the surface of the ground, which is the greatest depth at which defensive mines are ever placed.

The two preceding proofs were, without doubt, sufficient to establish the reality of the globe of compression, and shew how erroneous had been the opinions of former miners. They were further corroborated at Potsdam, in the presence of Frederic II., King of Prussia, by the engineer Le Febvre. As that officer carried on his operations in sand, he thought the L.L.R. should be increased, and therefore he made it 15 feet. He constructed three galleries, distant respectively from the mine 24, 32, and 42 feet: under the charge was a gallery distant from it 16 feet. All the galleries were 5 feet by 3 in the clear, and were lined with oak casing: 30 feet from the great mine a smaller one was constructed at the same depth. The charge of the first was 3000 lbs., and the following was the result.

The crater was 66 feet in diameter and 18 feet deep, free from rubbish, and perfectly smooth.

After such authenticated proof, there can be no doubt of the existence of the globe of compression. Practice and theory here coincided exactly: thus, instead of contesting results which did not admit of a doubt, it would have been far better, during Belidor's life, to have tried on the one hand to make them serviceable for the attack of defensive mines, and on the other to prevent their destructive effects.

However this may be, Belidor proposed to reach and blow in at a great distance,

by means of his globes of compression, the subterranean works of the besieged: he observed truly, that the latter could not profit by the discovery; 1st, because it required too great a consumption of powder; 2ndly, without driving very long branches in front of his galleries, these would run the risk of being blown in; 3rdly, because the masses of earth thrown up by these explosions afforded too good cover to a besieger. Thus the author of the discovery concluded that it would entirely be in favour of the besieger; and some time after, globes of compression served as a powerful auxiliary in opening the gates of Schweidnitz to Frederic the Great. In the works of Le Febvre may be seen an account of this memorable siege, during which the Prussians fired four globes of compression, the last of which blew in the counterscarp, driving the rubbish against the very revetment of the fortress, forming thereby a ramp as practicable as that produced by a breaching battery. It is to be regretted that Le Febvre, who directed the attack, and who ought to have visited the mines of the besieged after the surrender of the place, has not made us better acquainted with the detail of these new proofs. It would have been interesting to know at what distance from the mines the galleries were,—if they were ruptured, and for what length,—if the gases of the powder fired in the globes of compression penetrated into some galleries, and there spread so as to drive the besieged away. The silence preserved by him on these points leads to the supposition that he did not obtain from his mines all the effect he expected: and what makes this opinion still more probable is, that ten or twelve hours after the explosion of the two first globes, the besieged gave 'the camouflet' to the Prussian miner who was established in their crater.

This circumstance at the siege of Schweidnitz, recorded in the writings of Le Febvre himself, has renewed the old disputes on the discovery of Belidor; and some modern miners have gone so far as to deny the existence of the globe of compression. Notwithstanding the talents and reputation of these anti-globists, as Le Febvre called them, it must be confessed that the reasons which led them to this singular conclusion have not much foundation. Let us suppose that the gallery *a*, *b*
Plate VI. (fig. 4) is blown in for the length of 30 feet or so, and that the besieger, having crowned the crater, sinks a shaft (C) a little to the right of his lodgement: there is no doubt, if the gallery be still sufficiently ventilated, that the besieger can, without loss of time, go to meet his under-ground foe, and give him the 'camouflet' after a lapse of some hours, as done at the siege of Schweidnitz. All that we have a right to conclude from such an occurrence is, that the gases of the powder penetrated into the galleries in small quantities.

Of all the opinions broached on this important process, those of Mouzé appear the most sound. This talented miner, observing that the galleries of Schweidnitz almost all presented their ends towards the besieger's mines, suspected that in this favorable position they afforded less bearing to the effects of the powder, the explosion of which would, in a similar case, confine itself to overthrowing some frames. This remark of Mouzé's was very judicious; and although not borne out by experience, he made it, as will be seen hereafter, one of the fundamental principles of his system of defensive mines.

Bousmard, the learned author of an 'Essai Général de Fortification,' does not concur in the opinions of the 'anti-globists.' He supposes, with reason, the effects of globes of compression to be sufficiently confirmed: he admits that they are capable of destroying galleries at a distance from them equal to four times their line of least resistance; and combining these data with the time requisite for their construction, he also calculates the duration of a system of defensive mines in the following manner.

Let us imagine the glacis of a place to be mined to a distance of 240 feet from the crest of the covered-way, and suppose that the besieged either does not try to prevent the placing of the globes of compression, or that he fails in the attempt.

This is a supposition impossible to be admitted with reason, but may be assumed for a moment, the better to analyze the nature of defence by which the lapse of time is estimated. This granted, the besieger, by the mere force of circumstances, finds himself arrested nearly a month on a glacis, such as has first been treated of.

If he breaks ground at 40 yards from the head of the farthest gallery, by means of shafts 18 feet deep, their excavation will require twenty-four hours at least; and the radius of the crater of the globes of compression requiring to be 18 yards, each of Plate VIII. the branches (fig. 1) ought to be at least from 24 to 26 yards in length, in order that the parallel from which they break out may suffer no harm from the explosion. These branches will consequently require from 4 to 4½ days' labour: the transport of powder at night,—the necessary time for loading the mine,—the placing the casing for the hose, and the tamping of the long branches,—will require at least 1½ day, which gives—

	Days.	
For the establishment of the first globes of compression, nearly	7	
For forming a lodgement to crown the crater of each of these globes	1	
The globes of compression of the second attack require:		
1st, Sinking shafts	1	4½
2nd, For branches 6 yards long, at the end of which each new globe is formed, ...	1	
3rd, For the transport of powder, the excavation of the branches, and the tamping the shaft, ...	1½	
Similarly, for the globes of the 3rd attack, ...	4½	
" " 4th "	4½	
" " 5th "	4½	
Total	25 days,	

which may well be reckoned as 30, including casualties and delays which always accompany a work of this nature.

But, adds Bousmard, how much more may the besieged retard this work, both by sorties, by spies, and by watching the transport of the wood for casing the shafts and galleries, as well as the heaps of earth which accrue from their excavation? He may form on the parapets trench cavaliers opposite the most considerable heaps, and the earth of those which are of a fresher colour than the rest. By these means he may discover the spot from whence the miner is detached, before the latter gets to the bottom of the shaft.

The delays occasioned by 'camouflet' mines and the subterranean arrangements of the besieger cannot be estimated at less than a month, which gives a duration of two months which countermines add to the defence of fortresses. It may be seen that the method proposed by Bousmard for the attack of defensive mines, by means of globes of compression, is the same as that followed by Le Febvre at the siege of Schweidnitz.

The Russians, in their last war with the Turks, took advantage of this method, not to destroy countermines, which the latter had not, but to open the counter- Plate IX. scarps of fortresses they attacked, and drive the rubbish against the foot of the revetments, the upper part of which had previously been brought down by guns. This operation succeeded completely at the sieges of Choczim and Bender, where

they thus managed to make practicable breaches. It would be very interesting to possess the details of these different experiments. If a series of experiments, well authenticated, could be collected, and the circumstances of them combined, we might perhaps be able to arrive at satisfactory conclusions, and solve the following important problem:

Given the width and depth of the ditch of a work,—it is required to find the radii of explosion of an overcharged mine both vertically and horizontally, and the quantity of powder necessary to drive the ruins of the counterscarp against the opposite revetment, so as to form there a practicable ramp.

Although Belidor was the inventor of globes of compression, he did not suspect them of possessing this singular property; at least no trace of it is found in his works, and chance alone discovered it at the siege of Schweidnitz.

SECTION IV.—METHOD OF CONVERTING A GALLERY, OF WHICH THE BESIEGER MAY HAVE OBTAINED POSSESSION, INTO A TRENCH—METHOD FOUNDED ON THIS PRINCIPLE FOR THE ATTACK OF COUNTERMINES.

Not satisfied with having given to the besieger mines whose effects would be very extended, Belidor at the same time found out a simple way of converting into trenches the defensive galleries which had been seized. Supposing that an entrance has been effected into a gallery, he proposes placing at different intervals heaps of powder having a common hose among them. By firing them, the roof of the gallery is blown off, and if the charge has not been too considerable, a sort of ditch about 2 yards deep is formed on the surface of the ground, on the brink of which the earth raised by the explosion forms a parapet on either side.

In the experiments carried on at Bizi, miners penetrated into a listening gallery which was 40 yards in length, by means of the crater of a mine; at the same time they seized 24 yards of one gallery, and 12 of another. At the ends of these galleries retrenchments were made of sand-bags. The hose was then laid; ten barrels of powder in two lots in the transverse gallery, sixteen in four lots in the longitudinal gallery, and as many more in the listening gallery, were laid respectively; the entrance through the crater was stopped up: all this took seven hours to complete.

The ground above the galleries was carried away by the firing of this charge, and the galleries were thus changed into trenches 8 yards wide by 2 or 3 yards deep.

Though these trials were renewed by Belidor himself, they are not yet sufficiently numerous to allow of rules being applied to them with certainty, suitable for different soils.

Belidor says that the heaps of powder ought generally to be 12 yards from centre to centre, and that for ordinary ground each lot or heap ought to contain three times as many barrels (each filled with 110 ℔s. of powder) as there are yards in one-fourth the depth; that is to say, for a gallery 48 yards long, the floor of which is 6 yards under-ground, eighteen barrels, divided into four equal lots, would be required.

This rule, founded on experience, will suffice for any general applications that may be made of it; in it consists the method by which Belidor proposed to attack countermines, and by which he expected to reduce fortresses in a short time, by using their own galleries against them.

To give an idea of this, suppose *c* (fig. 1) to be the salient of an attacked front, *a b*, *a b*, and *a d*, three galleries of the besieged: Belidor excavates from his third parallel, in order to establish a globe of compression: this placed, he admits two different ways in which he might be opposed.

The besieged may first fire a mine to stop his work, and destroy the lodgement L: in this case Belidor crowns the crater, at the same time that a miner is endeavouring to discover the branch, break into it, and push on as far as the gallery of the besieged, which he attacks with all his strength, and endeavours to seize at any cost.

Supposing the besieged does not prevent the construction of the globe of compression, it is fired, blows in the nearest gallery, and drives him away. The earth is then excavated before the air has been renewed in the enemy's gallery; they try to find the ruins of it, and enter and attack it vigorously, and retrenchments are made as in the former case.

In applying to galleries which have been seized the rule before given, Belidor converts them into trenches, and thus gains considerable cover, safe communications, and immense parallels, through which he proposes to lead the troops.

This method of attack is doubtless ingenious, and easy of application: it can be employed in many instances, and its effect would be decisive; it would not only destroy the galleries belonging to the besieged, but also the retrenchments and barricades that might be built by them.

It cannot, however, be expected that by this method exclusively a system of countermines can be destroyed. The besieger would in reality be obliged to renew frequently his attacks, so as to become master of the gallery; and it must be admitted that if the besieged knows how to make use of his position, the result of these combats would be often uncertain. Belidor has perhaps attached too much importance to his discovery, in applying it to all the systems of mines known in his time, the attack of which he has described, according to his new method, in his manuscript treatise on Subterranean Warfare.

This idea of taking places by means of their own mines appeared so engaging to him, that he proposed the building of galleries to places devoid of them, so as to convert them afterwards into trenches. As experience teaches us that a sapper can advance 160 yards above-ground in twenty-four hours, while a miner can scarcely build 4 yards of gallery in the same time, it is very doubtful whether this last idea of Belidor is within the limits of probability.

The 'History of Sieges' gives several examples analogous to those proposed by our author; and he himself affirms that in the war of 1701 the allies had recourse to a sort of covered sap, which they made use of with success at the sieges of Tournay and Bethune.

They marched boldly, he says, between two horn-works, without running any risk from the tremendous fire kept up from the branches of these works, and arrived as far as the salient angle of the covered-way. They went under-ground to the depth of 2 or 3 yards by means of straight galleries 3 feet wide, 4 feet high, and 2 yards in length: when these small portions of galleries were completed, the earth above was blown away, then widened, and zig-zags excavated where necessary.

This example, although not very different from mining, may find applications in the attack of places liable to inundations, and which can only be approached by means of dykes or narrow causeways.

SECTION V.—ON THE FORMATION OF BREACHES BY MINES.

Since artillery has been so greatly augmented in armies, breaches have been made by guns in fortified places.

The method of making breaches by mines being slower, more dangerous, and less certain, has been abandoned in the present age. As, however, instances may

occur in which an army without artillery finds itself obliged to carry an important post surrounded by a scarped wall, it is necessary to give some details on this subject.

When the besieger has established himself on the crest of the covered-way, and has effected a descent into the ditch, he pushes forward a sap to the foot of the revetment of the work he is attacking, supposing the ditch to be dry; if not, he ought to fill it up, and construct an epaulement on the side of the flank, as is done at the attack of places. He then places against the revetment the planks *c* (fig. 1), 2 or 3 yards long, 1 foot wide, and 4 inches thick: these are covered with tin, to resist fire: they are made to lean against the wall, leaving sufficient room for two miners to rest conveniently, and work at their ease. Finally, the besieger covers them with raw rides, and forms an epaulement with sand-bags, to protect the men from the fire of the collateral works.

Plate VII.

The miners, under cover of the planks, then work to break through the revetment, and bury themselves in the wall as fast as possible. The entrance, or 'eye of the mine,' as it is technically called, ought to be a foot above the level of the water,—supposing that the enemy have no means of raising it by inundating the ditch: without this precaution, there is a risk of the work being inundated; and, as a general rule, the miner should always commence work one foot above the level of highest water.

When it is possible to erect a battery of one or two guns on the covered-way, to cover the miner, the opportunity should not be lost. In aiming constantly at the same spot, a hole 1 or 2 yards deep is soon opened, into which the miner gets, and is soon under cover from the fire of artillery or musketry from the flanks, as well as shells and grenades, which are rolled down upon him from the top of the rampart. He has then only the sorties and the mines of the besieged to fear.

The miner ought to enter the revetment by a horizontal gallery at right angles to the direction of the face of the work which he is entering: this little gallery is $3\frac{1}{2}$ feet high by $2\frac{1}{2}$ feet broad. When he gets to the earth of the rampart, he drives two galleries, right and left, which are directed along the inner side of the revetment wall, and which are 2 feet 6 inches high and 2 feet wide: their length varies according to the thickness of the wall, and the mines placed at their ends should be so regulated that their lines of least resistance may meet at a point.

At the end of the branches, the chambers of the mines are dug so that one-half of them is in the masonry of the wall. Vauban states that this is the best method of obtaining the greatest effect: when mines can be established in the counterforts, care is taken to do so. A twofold advantage is gained by this; the powder acts with more certainty on the outside of the revetment, at the same time that the counterforts destroyed completely leave the earth to support its own weight.

When the chambers of the mine are completed, the powder is brought up in sand-bags; they are then loaded and tamped. The firing should be simultaneous, in order that the explosion of the mines taking place together may produce the more considerable results.

Plate VII.

Fig. 2 shews instances of mines thus bored in the thickness of the rampart: it is taken from a treatise by Vauban. Other mines, besides those behind the revetment, are there shewn in the earth, to render more certain the overthrow of the revetments, and to facilitate the ascent of the breach.

It may happen that behind the revetment where the mineris detached, a gallery *a* or *b* (fig. 1) may exist. In this case the besieged can annoy his enemy greatly, and retard considerably the placing of the mines. The besieger ought then to try to break into the gallery, by means of a petard, when there is before him only a slight

partition of masonry. When he once effects an entrance, grenades and fire-balls should be thrown in, to drive away the enemy for at least some time: he then widens the opening, and prepares to attack the gallery by storm. If he drives the enemy out altogether, or partly, he retrenches himself, and then commences establishing a mine.

When the gallery in the wall of the escarp is sufficiently retired towards the interior of the work, the besieger may then save a great deal of time and trouble by sacrificing a proportionate quantity of powder. It will only be necessary to form a breach, to close the two ends of the gallery (if open at two ends) by sand-bags and logs of wood laid across, and to collect in the space between a great quantity of powder in heaps. The explosion will bring down the whole of the face of the work. Some proofs of this expeditious mode of proceeding have been made.

In the preceding it has been supposed that the wall required to be opened has earth at the back; but it may happen that a breach is required to be made in a castle situated in a defile where cannon cannot be transported.

Plate VII. In this case, suppose *a a*, fig. 2, to be a wall first required to be opened for a mine: the thickness must be ascertained as nearly as possible; a gallery *b* is then commenced at the foot of the wall, which is driven to the middle of it; returns are made at right angles to this gallery, and at the end of them are placed the mines *c c*: the explosion of these taking place simultaneously will throw down a greater portion of the wall.

This supposes the wall to be 3 or 4 yards thick; but if it be only 2 yards or less, it will be necessary to establish one or more mines under the foundation, supposing the ditch to be dry, taking care to place them in the middle of the whole width. To overthrow a wall only 2 or 3 feet thick, it is sufficient to place one or more barrels of powder against it.

APPENDIX I.

*Observations upon Mine Frames for Field Service.**

When the mining practice commenced at Chatham, in the year 1812, the system which was then adopted was not that now in use, called 'chassis à la Hollandaise,' but the earth of the galleries was supported by means of a frame of peculiar construction, admirably suited to the purpose, resembling in some respects a common door-frame.

This frame was composed of a capsill of from 4 to 6 inches in depth (according to the size of the gallery) and 4 inches in width; of stanchions 4″ × 4″; and of groundsills 4″ × 2″; and they were put together without nails or screws, or other fastenings, and were not subject to derangement.

The frames were placed at intervals of from 3 to 4 feet apart, according to the nature of the soil, and formed the support of a series of planking, 9 inches wide and 2 inches thick, called the 'top sheeting,' which was lodged upon the capsills, and of other planks, 9 inches wide and 1½ inch thick, which supported the sides of the gallery, and were called the 'side sheeting.'

On the bottom of the gallery, the groundsills alone rested, and were let into the floor, so as to be flush with the surface of the ground.

Some years later, for some reason which I have never understood, this system (which was copied by some of the continental nations) was abandoned by us, and recourse was had to the system called the 'chassis à la Hollandaise.'

* By Colonel Sir Frederic Smith, R.E.

This is a case composed of 4 pieces of plank, of from $1\frac{1}{2}$ to 2 or $2\frac{1}{2}$ inches in thickness (according to the size of the gallery), and the width depends upon that of the planks which can be obtained.

The form of this case is rectangular, and both the capsill and groundsill have two notches at each end, while at each end of both the stanchions there are tenons corresponding to those notches.

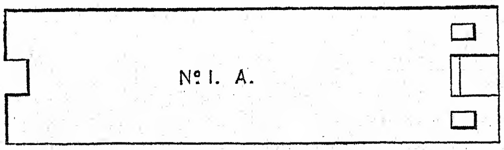
Each of the stanchions is hollowed out on both edges near the middle of its length, to admit of its being more easily handled by the miner, and for pickets being driven through the opening thus formed into the sides of the gallery, to keep the stanchions more steadily fixed when used for the support of ascending or descending mines.

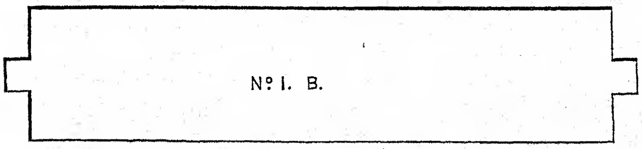
In the practice at Chatham it is found necessary to cut away more of the head of the gallery than the mere height for the case when placed, to allow of its clearing the top of the tenon in the act of placing it, after which it is dropped into its place; therefore an interval is obliged to be left between the upper surface of the capsill and the earthen roof of the gallery, equal in depth to the height of the tenon.

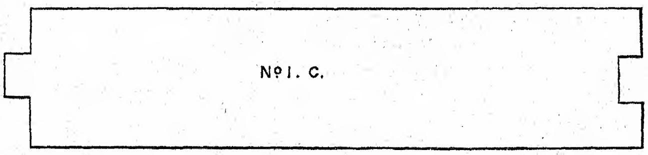
It was found that this gave the opportunity for a settlement of the ground; and this induced Serjeant-Major Jones* to suggest an alteration of the frame, which, to a certain extent, is an improvement.

It will be seen, from what has been stated above, that a capsill will answer the purpose of a groundsill, and that the stanchions are suitable to either side of the gallery.

In Serjeant-Major Jones's proposition, one end of the groundsill had a notch cut in it, to receive the tenon of one of its stanchions, that stanchion having two tenons. The other end of the groundsill has a cleat nailed upon the surface, in a position corresponding with that of the notch at the other end. The stanchion for this side has also a notch cut to fit over this cleat, and at the other end of the stanchion there is a tenon, like that on the opposite side of the case. The capsill has a notch at either end, to receive the corresponding tenon.



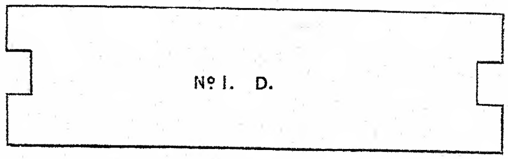




In placing this case the groundsill is first bedded, then the left stanchion is placed perpendicular to the groundsill, one of the tenons being inserted into the notch.

* Now Quarter-Master, Royal Sappers and Miners.

The capsill is then placed so that its left notch receives the upper tenon of the left stanchion, and then the tenon of the right stanchion is partially inserted into the



corresponding notch of the capsill; but this stanchion is inclined, with its heel approximating to that of the stanchion previously fixed, and is then gradually slid along the surface of the groundsill till its notch passes over the cleat, when two pickets are driven through mortise-holes on either side of the cleat, to keep the stanchion from being forced out of its proper position.

This system gives a facility not only in placing the frames, but in removing them for the purpose of tamping a gallery, which is often a difficult operation, if there be much pressure of ground on the capsill in the old system.

The disadvantage of this plan is, that the stanchions are not of universal application, being of different form; the one having two tenons, and the other only one.

The groundsill will answer for the capsill, if both are supplied; but if by any want of arrangement either should be deficient, a superabundant quantity of the other will not supply its place.

A consideration of Serjeant-Major Jones's proposal led to a simplification of the mine case, which may be described as follows.

In the first place, the groundsill and capsill are identical in form. Each has a rebate at both ends, of the same width as the thickness of the stanchions, and running across the whole width of the plank, its depth being half an inch. The stanchions are mere rectangular pieces of board, without any workmanship whatever upon them, excepting an auger-hole through the centre of each, for the purpose of picketing them to the sides of the gallery.

As in the former instance, the groundsill is first lodged in its position; then one of the stanchions, with its end resting on the flat surface of the rebate; afterwards the capsill is placed with the rebate at one end resting upon the upper edge of the stanchion; and lastly, the opposite stanchion has its upper end placed in contact with the corresponding rebate of the capsill, whilst the lower extremity or heel of the stanchion rests upon the middle of the groundsill, and is gradually moved along its surface, until it drops into the rebate at its own end.

So far as simplicity of construction and the more general application of its parts are concerned, this case appears to be an improvement upon that of Serjeant-Major Jones for galleries and branches, but it is not, like his, applicable to shafts.

With the simple case last described, the excavation will be very little more than that required for Serjeant-Major Jones's case,—merely the extra half-inch at one side, to allow of the depth of the rebate; but practically this is of no importance.

In the mining operations of the year 1847, at Chatham, the cases of all three descriptions were in common use; and as there was an abundance of each at hand, with a store suitably placed with reference to the work, no inconvenience or confusion arose from the misplacing of the several parts employed.

Any practical miner, capable of using a saw, could make the more simple case without difficulty; and it is obvious, that in preparing these cases there is a considerable saving of time.

For preparing this case, the only tools required are the saw and the auger; and

in the other, the following additional tools would be necessary, viz. a gimlet, a hammer, a chisel, and a mallet, with nails.

In very loose soil, it is found difficult to drive a gallery supported by either description of case that has been described; whereas there is scarcely any soil (but a running sand) in which the original frame and planking of 1812 could not be used.

In the old system in question, the planks were inserted over the heads of the capsills, and behind the sides of the stanchions, and were driven gradually forward in advance of the workmen, by means of chases cut out with a push-pick; false frames being occasionally used, to support the more advanced ends of the planks. I believe, on the whole, that the old plan was the best. F. S.

APPENDIX II.

Memoir on the Object of the Breaching Experiment carried on at Bapaume in 1847; *and on the present State of the Science of Military Mining.**

1. All experiments of breaching by mines should be directed to two principal points:

First, on the best mode of attaching the miner, and of arriving in the shortest time at the proposed chambers of the mine.

Secondly, on the position of those chambers, and of the charge proper for the mines.

Mode of attaching the Miner, and of arriving in the quickest Time at the Chamber.

2. Vauban attached the miner about 2 feet above the bottom of the ditch: he regarded the operation as a difficult and dangerous one, and recommended that a gun should be brought into the covered-way, or to the foot of the descent, and a few rounds fired from it, to indent the wall sufficiently to afford some cover to the miner when attached. He thought this mode of affording cover to the miner much preferable to placing planks for this purpose against the escarp, forming a sort of lean-to roof.

3. The same effect has been attempted to be accomplished by firing wall-pieces against the escarp, but without success.

4. A bag of powder placed against the wall, and covered with sand-bags, has also been proposed; but sufficient experiments have not yet been made to decide whether this mode of operating, in order to obtain cover for the miner when attached, would be always successful.

5. The Committee of Fortification recommend that the miner should pass under the wall in sinking a small shaft and driving a gallery under the foundation. This suggestion would only be practicable in situations where neither rock nor water would impede the miner.

6. The Committee of Fortification also recommend that miners should be attached to the escarp at two points, separated by intervals of about 10 feet.

7. If the ground is not difficult to excavate, it is better only to sink so deep as to allow the gallery just to pass under the foundation of the escarp; the foundation itself forming the top of the gallery.

Positions of the Chambers of the Mines and their Charge.

8. All Engineers are of opinion, that in order to make a breach, it is better to put too much powder than too little; at the same time it is desirable not to project the débris too far. It is also necessary that the earth of the rampart should, by the

* Translated by Capt. J. Williams, R.E., from an unpublished Memoir of the French Committee of Fortification.

effect of the explosion, be so disposed after the fall of the revetment, as to form an accessible ramp: it is universally acknowledged that making a breach by a mine must not be considered as a simple demolition of the escarp.

9. Vauban retired the chamber of the mine from the face of the escarp at a distance equal to one-half or one-third of its height, in order to prevent the line of
Plate X. figs. 1 and 2. least resistance being vertical. This rule placed the chamber of the mines near the tails of the counterforts. He computed the charge with the line of least resistance measured from the chamber to the face of the wall, as for ordinary earth, allowing one-fifth to one-third in excess, to prevent the charge from being too small.

10. Cormontaigne placed the chambers of the mines in the same vertical plane as the tail of the counterforts, separated from each other by central intervals of
Fig. 3. 30 feet; each chamber therefore did not necessarily find itself behind a counterfort: his system was particularly applicable to breaching a salient: he verified the rule laid down by Vauban, viz. that the position of the charge from the face of the revetment should be equal to about one-third of the height of the escarp.

Principles upon which the Charges of the Mines were determined in the Demolition of the Ramparts of Vienna; par le Chef de Bataillon Constantine.

11. 21·594 lbs. (20 lbs.)* of powder are required in a common mine to raise 9·68 cubic yards (a cubic toise) of masonry. The following Table is computed upon this data.

H.	C.†	H.	C.	H.	C.
(6 feet.	50 lbs.)	(11 feet.	230)	(16 feet.	700)
7 "	75	12 "	300	17 "	830
8 "	95	13 "	370	18 "	990
9 "	125	14 "	465	19 "	1160
10 "	170	15 "	570	20 "	1350

The volume raised by the explosion was taken at $\frac{11}{6}H^3$. The craters were tangent to each other: where there was an escarp gallery, the line of least resistance was the distance from this gallery to the face of the escarp. The number of mines necessary was first determined from the assumption that they are separated by two-lined intervals; then one-half above the charge computed in the ordinary way was added, in order to allow for the powder being placed unconfined in the gallery, and for the suppression of the tamping.

When the quantity of powder has been calculated, it should not be spread over the floor of the gallery, but placed in heaps: more certain effects are obtained by this arrangement.

In order to secure the complete destruction of the escarp, the charge should be above the foundations, at a height at least equal to the line of least resistance: this position prevents the expansion power of the powder from acting unnecessarily deep.

Plate XIV. *Bastion Elend*, fig. 14.—The total charge of the mines was 7558 lbs. (7000): they were fired simultaneously: the revetment was completely overthrown, the masonry broken into small pieces, and the breach easy of access.

Bastion de Molech, fig. 15.—According to the Table, a mine with a line of least resistance of 14 feet (13) should be charged with 399·5 lbs. (370) of powder. On a length therefore of 153½ yards (72 toises), sixteen mines, charged altogether with 6392 lbs. (5920), will be necessary.

Another portion of the escarp was 85 yards (40 toises) long, with a line of least resistance of 15 feet (14), requiring as the united amount of the charges 4021 lbs.

* The figures placed between parentheses express the French weights and measures.

† H is the line of least resistance in French feet; C, the charge in French lbs.

(3720), making altogether an expenditure of 10,408 lbs. (9640) of powder. One-half of this amount was added as a measure of precaution, giving a total of 15,612 lbs. (14,000) of powder. The tamping consisted of the gallery being tightly occupied in four places by pieces of split wood about 2½ feet long. The powder was disposed in heaps of 1000 lbs. along the faces, and of 2000 lbs. at the salients and shoulders. The escarp was quite destroyed: but little noise accompanied the explosion, nor did it occasion pieces of masonry to be projected to any distance. The earth of the rampart disposed itself, after the fall of the wall, as in figure 14. The tamping formed of wood had been moved bodily, and with much violence, along the gallery.

Plate XIV.

Plate XV.

Bastion de Burg, fig. 20.—The bastion was destroyed by placing the charges in an escarp gallery. This gallery passed through the counterforts: where it became narrowed, between each counterfort, a chimney or flue led the whole height of the escarp, and communicated with the air. The escarp gallery extended along the faces and flanks of the bastion for a distance of 320 yards (150 toises). Each mine required to be charged with 1069 lbs. (990) of powder, and twenty-five mines were required to destroy the whole length. The charges, therefore, amounted altogether to 26,722 lbs. (24,750), which, with the addition of one-half to insure full effect, made a total of 39,949 lbs. (37,000.)

But in consequence of the great length of the gallery, causing a corresponding augmentation of powder, the mines were only loaded with 35,630 lbs. (33,000.)

The entrances into the galleries were tamped with wood and earth: 5938 lbs. (5500) were placed at the salient; 4859 lbs. (4500) at the left shoulder, and 3779 lbs. (3500) at the right shoulder; the charge at the latter point being diminished from the apprehension of damaging the bridge which stood in its vicinity. Three intermediate heaps, each amounting to 2267 lbs. (2100), were placed between the salient and each shoulder. In the centre of the right flank, a mine charged with 2100 lbs. was placed, and another of 2375 lbs. (2200) in the centre of the left flank: 2700 lbs. (2500) were employed in communicating by a train the fire along the whole extent of the demolition.

On the right face, the staves of the powder barrels were broken on one side when placed in the chamber. The same arrangement was made on the left face; the barrels were staved on one side, and the powder was afterwards placed in heaps. Notwithstanding a proper arrangement had been made to secure simultaneous explosions, the mines on the left face were the first to ignite. The report of the explosion was heavy, resembling that of common mines in ordinary earth with a line of least resistance of 20 feet. But few fragments of masonry were projected vertically, but some of the wood which had been employed in tamping the chimney was thrown 200 yards (metres) from the escarp. The bastion was in ruins, with an easy access from the ditch into its interior, along the whole extent of its contour. The salient angle was not, however, thrown completely down; the angle of the right shoulder also remained standing. On the right face some fragments of the counterforts, situated between the charges, presented inaccessible portions. On the left face, the greater part of the masonry, after having been pushed forward 16 metres, fell, with its lines of fracture converging towards the charge, while the disposition of these fissures on the right face took an opposite direction.

Curtain 7, 8 (no figure given).—The curtain had a relief of 47 feet (14·6 metres). Twenty-two shafts, 25 feet 4 inches (7·80 metres) apart, were sunk in the parapet to a depth of 35 feet 10 inches (11·30 metres): a small branch was driven out from their bottom till it reached the masonry, in which the powder was lodged so as to have a line of least resistance of 12 feet 8 inches (3·90 metres). Each mine was loaded with 287 lbs. (130 kilo.) of powder. The small branches were tamped with

turf and wood, the shaft with earth well rammed at every 3 feet. No precaution was taken to fire the mines simultaneously; the demolition of the curtain was complete, without a wide dispersion of fragments, and without report or violent shocks.

Cavalier 7.—The walls were more than 20 feet thick; branches were driven 12 feet into the masonry, measured from the face of the escarp. Each mine was loaded with 215 ℔s. (200) of powder instead of 324 ℔s. (300); arrangements were made by the disposition of the hose to effect the simultaneous explosions of the mines. The effect of the explosion was to throw down the face of the wall for a thickness of 2 feet, the remainder of the masonry remaining in its place. The tamping of the branches was blown out. In driving the branches through the masonry, the former were never advanced quicker than 13 feet (4 metres) in twenty-four hours, with a working party of six miners.

In shafts which did not require lining, the sinking progressed at the rate of 1 foot (0·32 metre) per hour; branches in brick-work, with a working party of four miners, advanced 3·3 feet (1 metre) daily, very regularly; in stone-work, as bastion No. 7, this rate was reduced to 1 foot (0·32 metre).

Shafts with lining were paid for at the rate of 3 francs per running metre; if not lined, one-half that price was paid: branches driven through masonry, at 6 francs per metre run. The miner not employed at task-work was paid 0·75 franc daily; sapper 0·70; other soldiers 0·50 each.

These prices, however, varied towards the conclusion of the demolitions; task-work was paid for at double the above prices, but it was found that the increased price did not accelerate the progress of the work. The tamping had been completed in nine hours; but with a strong working party, eight men were usually employed in tamping a shaft with a gallery leading from it: if, however, only a shaft, the number of men was reduced to four; half were sappers and half miners.

Demolition of Ulm in 1806, *under the Direction of the Commandant Breuille.*

12. The masonry was assumed to require 2·7 ℔s. (1·25 kilo.) of powder per 1·308 cubic yard (cubic metre), and 1·65 ℔s. (0·75 kilo.) for the same volume of earth.

Plate XIV.

The shaft No. 1, fig. 16, was made in eight hours; the chamber in half an hour: loading occupied a quarter of an hour, the charge being 80 ℔s. (36 kilo.) Two planks jammed in the shaft, and 1 foot (0·09 metre) thick formed the only tamping. The explosion was accompanied with a loud noise; the counterscarp thrown down for a length of 23 feet (7 metres); the débris from the breach was thrown more than 26 feet (8 metres).

Shaft No. 2, fig. 18, sunk 3·3 feet (1 metre) in rear of the masonry, had a line of least resistance of 8·8 feet (2·70 metres): the charge was similar to that of shaft No. 7; the crater was formed on the surface of the ground, cracking, however, the wall and the neighbouring ground: 80 ℔s. (36 kilogrammes) of powder were subsequently placed behind the wall, the tamping made good, and a breach, 9 metres in length, was formed by the explosion.

Shaft No. 4 was disposed as No. 2, but charged with 159 ℔s. (72 kilo.) of powder: 30 feet (9 metres) running of counterscarp were overthrown.

Shaft No. 5 was charged as No. 4, but the chamber was placed 6·5 feet (2 metres) from the face of the wall. The charge computed for ordinary earth would have been 200 ℔s. (75 kilo.) The explosion produced a crater the diameter of which was 14 feet (4·40 metres). The wall was thrown a little from the vertical, and was cracked for a length of about 13 feet (4 metres): the explosion was very loud; pieces of the top frame were thrown to a distance of 218 yards (200 metres).

Shaft No. 6.—The mine was placed 5 feet (1·50 metre) from the face of the wall, and loaded with 192 ℔s. (87 kilo.); the tamping was not made in the usual manner with earth, but formed with wooden struts jammed across the shaft. A crater was produced of 16 feet (5 metres) in diameter and 3·3 feet (1 metre) in depth; the wall was pushed forward, opposite the chamber, for a distance equal to 10 inches (0·25 metre).

The report of the explosion was extraordinary; a piece of wood was projected 874 yards (800 metres).

Shaft No. 7 was 16 feet (5 metres) deep, and placed 6·5 feet (2 metres) from the interior face of the revetment: the charge was 343 ℔s. (128 kilo.), disposed as in the preceding experiment. The wall was overthrown for an extent of 45 feet (14 metres), forming a practicable breach for the distance of 30 feet (9 metres) on one side of the former breach, and 16 feet (5 metres) on the other. The mine was surcharged towards the masonry.

13. *At the periodical inspection at Montpellier, in* 1833, *M. le General Valazé* directed a counterscarp to be overthrown, with a view of obtaining cover, amidst the débris, to cross the ditch, and gain the breach. This project was not considered a very advantageous one; but it will be examined here, in consequence of its bearing with mining operations. The counterscarp (see fig. 10) was 21 feet (6·4 metres) high, 6·6 feet (2 metres) thick at the base, composed of bad masonry; a shaft was sunk 16·3 feet (5 metres) deep, and the chamber of the mine placed in a small return 8·4 feet (2·60 metres) from the face of the wall. The charge was 375 ℔s. (170 kilo.), that is to say, an ordinary charge, computed for a line of least resistance of 16·3 feet (5 metres); but admitting that masonry is double the weight of ordinary earth, this charge is a surcharged one on the side of the masonry. The explosion produced a crater 16·3 feet (5 metres) in radius in the covered-way, and one of 23 feet (7 metres) on the side of the masonry. To form a crater of 23 feet (7 metres) radius in common earth, with a base of least resistance of 8·4 feet (2·60 metres), would have given $n = \frac{7}{2\cdot60} = 2\cdot68$ (8·4 feet): the side of the powder-box would therefore have been $B = \frac{T}{8\cdot5}(1\cdot05 - 0\cdot05\,n) = \frac{T}{8\cdot5}(1\cdot05 - 0\cdot05 \times 2\cdot68) = 0\cdot82$ (0·916) = 0·745 metre (2·43 feet), corresponding to 827 ℔s. (375 kilo.), which is more than double the charge of 375 ℔s. (170 kilo.) employed in making the crater in vertical masonry.

Plate XII.

See formula 5, page 404.

This experiment points out two facts equally important to note: 1st, That for vertical masonry to produce a given crater, requires only half of the charge required for producing the same crater in common earth. 2nd, That notwithstanding the facility with which the masonry has given place in a vertical direction to the explosion of the mine, the crater in the covered-way has preserved the same diameter as it would have done had it been exploded under common earth.

Plate XII. figs. 9, 22, and 23.

14. Among the experiments made at Metz, in 1834, a counterscarp was overthrown by two mines. The mines were placed in the earth; the line of least resistance was 7·8 feet (2·40 metres) in the direction of the masonry, and 13·2 feet (3·06 metres) to the surface of the ground. The charge, in earth, for a line of least resistance of 7·8 feet (2·40 metres) is 53·6 ℔s. (20 kilo.): the actual charge used in this experiment was 132 ℔s. (60 kilo.); first, to allow for the masonry, the co-efficient of which was taken at 2; and because the charge, computed as above, for earth, was considered as small. The radius of the crater was nearly 13 feet (4 metres), corresponding to a charge of 222 ℔s. (83 kilo.) in common earth: the vertical masonry had not resisted more than earth; but, on the other hand, must be

Plate XV.

remarked the wide interval of the mines, 47 feet (14·5 metres), and the adhesion of the masonry within itself, shewing that if the craters had overlapped, so as to have made $n = 3$ at a minimum, then the charge for common earth would have been 122 ℔s. (55·7 kilo.) in place of 132 ℔s. (60 kilo.)

Plate XI. figs. 5 and 6.

15. At the siege of Antwerp, in 1832, the escarp of the lunette St. Laurent was found to have the following construction. It was built 'en décharge,' the arches having a span of 8 feet (2·50 metres), resting on counterforts 3 feet (1 metre) broad, and 14 feet (3·40 metres) long. The mines were separated by intervals of 19 feet (6 metres); the two extreme ones were placed immediately behind the counterforts, the intermediate one a little in rear of this alignment. The charge, which, computed by Vauban's rule, would have been (62·30 kilo. + $\frac{1}{3}$ (62·30) = 84 kilo.) 225 ℔s., or computed by the formula deduced from the experiments made at Metz in 1834, would have been 375 ℔s. (140 kilo.), was increased to 1103 ℔s. (500 kilo.) per mine, from an assumption that the revetment, being strengthened with counter-arches, would offer greater resistance. The result was enormous, although the intermediate mine did not explode for ten minutes after the others. A breach was made on the two faces of the lunette, and the bridge of fascines across the ditch partly destroyed. Colonel Vaillant, however, succeeded in restoring the bridge and crowning the breach. A Dutch sentinel posted on the terreplein above did not know that a breach had been made, and did not leave the salient of the lunette.

Plate XI. fig. 8.

16. In the experiments at Metz, in 1834, an attack by mines was made on four counterforts; the charges of the extreme mines were placed in the counterforts themselves, and amounted to 463 ℔s. (210 kilo.); the intervening mines were placed at the roots of the counterforts, and loaded with 200 ℔s. (90 kilo.); a mine charged with 220 ℔s. (100 kilo.) was also placed in rear; the co-efficient of masonry was taken at 2, and in order not to disperse the splinters too widely, $\frac{3}{4}$ths only were taken: the charge was therefore $\frac{3}{4}$ of 2 C, or $\frac{3}{2}$ C = 210 kilo. (463 ℔s.), the half more than the charge for common earth. The explosion made a practicable breach, easy of access; the extent of wall breached was 98 feet (30 metres) in place of 66 feet (20 metres); the radius of the crater of the extreme mines was 19·8 feet (6 metres), with a line of least resistance of 15 feet (4·50 metres).

17. From an examination of the general abstract of the experiments made at Metz in 1834, drawn up by the Commandant Balmas in 1837, he concludes that in every case the mines ought to have been placed behind a counterfort.

18. General Guilleman, at the conclusion of a memoir on the demolition of counterscarps, says, "I have remarked besides, in a number of demolitions made by mines placed in the earth behind revetments, that if there was a depth of earth above the charge equal to the line of resistance on the side of the ditch, the demolition rarely failed; although the specific gravity and tenacity of the masonry and the earth, measured in the direction of the line of least resistance, differed so materially."

19. The rules given by Practical Miners being very discordant, it is desirable to inquire, by a comparison of these rules with the results of experience, how far they can be relied on; what they contain that is really true, or only specious, or altogether false: and as the results of the experiments at Metz can be most relied on, it is to them principally that our attention will be directed.

20. The first point to discuss is this, viz.: if masonry terminated by a vertical face, or a face a little inclined, offers as much resistance as masonry, or even earth, terminated by a horizontal plane, is it not more easy to throw down the masonry under the first condition, than to raise it under the second? Most practical miners conceive that there is no difference between the two cases. Let us see whether the experiments of Metz and Montpellier confirm this opinion.

21. In the breaches made at Metz in 1834, it has been seen (par. 16) that the mine was considered as made in masonry, for which a co-efficient of 2 was assigned, but it was loaded with only $\frac{3}{4}$ths of the computed charge. If the suppositions above alluded to had been true, the crater ought to have had a radius T, greater than 13·5 feet (4·15 metres); in place of which it is found that T equals 19·7 feet (6 metres); that is to say, that it was greater than the line of least resistance 15 feet (4·50 metres), and that the crater which had been made belonged to a surcharged mine, in which $n = \frac{6}{4 \cdot 5} = 1 \cdot 33$. It is admitted that the breach at Metz was well made; the splinters perhaps projected a little too far; but it is also obvious that the breach had not that form which theory assigned to it.

To explain the question more fully, let it be determined how a mine in ordinary level ground ought to be charged, to obtain a crater whose radius T will be 19·7 feet

See formula, paragraph 33. (6 metres). We should have $B = \frac{T}{8 \cdot 5}(1 \cdot 05 - 0 \cdot 05\,n) = 0 \cdot 705 \times 0 \cdot 92 = 0 \cdot 65$ metres (2·13 feet), corresponding to 551 lbs. (250 kilo.) of powder. From this it will be observed that a crater of 19·7 feet (6 metres) radius, which would have been produced in common ground, has been made in a vertical wall with 463 lbs. (210 kilo.) only; that is to say, with a charge less than that necessary for common earth, if the mine had been placed in a horizontal plane, and equal to that charge multiplied by a co-efficient 0·84, or to a charge whose side B of the powder-box would be multiplied by 0·91.

22. It results therefore clearly, from a comparison of these facts, that the charges regulated as in common earth are quite sufficient to make a breach in vertical walls. Vauban and Cormontaigne maintained that they were so; and it remains to be seen if the charge so computed be not a little in excess, as also whether there is no danger of the crater being made on the surface, as all miners have feared it might be, even when in this direction there was a line of least resistance greater than that towards the masonry, conformably with the remark of General Guilleman, par. 18.

23. Once admitted that the distance to the terreplein may be less than twice the line of least resistance, it will be concluded readily that it is advantageous, for the more complete *bouleversement* of the masonry into the ditch, and for overcoming the tenacity of the earth, to raise the mine as high as practicable; that is to say, to begin the branch 1·8 foot (0·60 metre) or 2 feet (0·80 metre), or even 3 feet (1 metre) above the bottom of the ditch, and to incline the sole of the gallery upwards.

24. The powder ought not to be lodged in the masonry near the face of the wall, as is sometimes done in considering the operation simply one of demolition, because the advantage of shaking and loosening the earth ought not to be lost sight of. Besides, the importance of celerity in mining operations renders the cutting out of the masonry a chamber for the powder-box an objectionable operation. The possibility of finding a portion of the counterforts standing after the explosion has generally been the cause of their being selected, in mining operations, as the points of attack. The position of the mines behind them satisfies to a sufficient degree the condition of having on the side of the terreplein a line of least resistance double that on the side of the masonry. It appears, then, proper to place the mines at the tail of the counterfort, and to allot one mine to each.

25. A breach 65 feet (20 metres) broad will, in general, be easily made in attacking three counterforts, and if the craters overlap much, the charge of the intermediate mine may be reduced. This reduction should, however, be a moderate one, provided the mine in rear is suppressed, which mine seems to have produced a bad effect in

the experiment at Metz, prolonging the time necessary for preparing the mine, with the defect that the best position of the mine has never been accurately determined.

26. It has been seen that miners at present charge their mines to throw down masonry in higher proportions than to raise common earth: it is shewn that Vauban gives an equal charge for both cases, under the condition of having on the side of the earth a line of least resistance double that on the side of masonry; and by Colonel Cassieres, Director at Arras, that the position of the line of least resistance should not be lost sight of. Paragraph 18 cites the opinion of General Guilleman, that a line of least resistance on the side of the earth, equal to that on the side of the masonry, is sufficient to insure the fall of the revetment. The experiments made at Metz in 1834 lead to the same conclusion; and paragraph 13 shews that the experiments made at Montpellier in 1833 confirm those executed at Metz.

When a breach is made in an escarp, the mine is usually placed in such a position as to satisfy the rule of Vauban, viz., of having on the side of the earth a line of least resistance double of that on the side of masonry; but this rule no longer holds when it is a question to throw down a counterscarp,—an operation the Engineer is more likely to be called upon to perform than the former, on account of the perfection with which breaches are made by artillery. The position of the charge of a mine in relation to the masonry and to the earth is, then, the most important subject of the experiment, and with which it is necessary to commence, since the charge and the disposition of the mine depend upon the result.

Plate XII. fig. 10. 27. It appears, from the Report of the School of Montpellier in 1837, that some experiments had been instituted at Metz and at Arras in 1831, on the powers of resistance of masonry galleries. They were exposed to the effects of the explosion of 441 lbs. (200 kilo.) placed at the bottom of a shaft hastily sunk without being lined with frames, and not tamped, but having a line of least resistance of 13·2 feet (4·10 metres). The charge had been doubled, to allow for no tamping being applied. From the results obtained the following conclusions are drawn:

1. That a gallery constructed in masonry resists a mine placed above it or on its flank at a distance from it equal to $\frac{6}{8}h$, and is ruptured at $\frac{5}{8}h$ (fig. *a.*)

2. That a branch with masonry of the same thickness resists $\frac{4}{8}h$ on the side, but gives a little more resistance above the extrados (diagram *b*).

Diagram *a.*

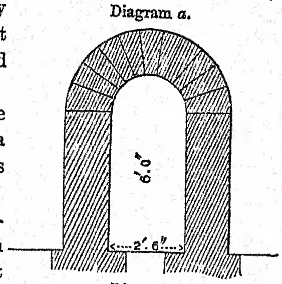
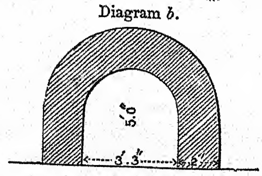


Diagram *b.*



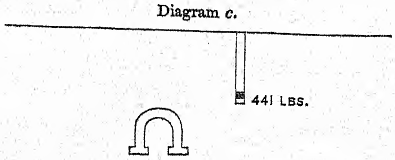
Constructed in 1829.

The experiments made at the School of Montpellier in 1837 were intended to prove if a branch can resist the explosion of a mine placed above it at a distance $\frac{3}{8}h$.

The branch was disposed as shewn in the annexed diagram *c*. The distance of the mine from the gallery was $\frac{3}{8}h$. The shaft was tamped by throwing earth rapidly into it, without tamping, ramming, or its surface being levelled.

It would have been desirable not to have filled the shaft at all, in order to try if, in doubling the charge, the tamping can be dispensed with. The branch was ruptured for a length of 10 feet (3 metres). From this experiment,

Diagram *c.*



and those made at Metz in 1831, it may be inferred that a branch in masonry having a thickness of 1·5 feet (0·45 metre) at the arch is broken by the explosion of an ordinary mine, when its distance from the chamber is not more than $\frac{3}{8}$ of the line of least resistance of the crater.

28. The following extract is taken from a work by General Chasseloup, published in 1811.

"It is usual to demolish the revetment in fortifications by placing the mines in the masonry: their explosion succeeds generally in throwing down the wall, but leaves the earth of the rampart, and even the parapet, standing vertical. I have endeavoured, however, by these explosions to produce a greater effect.

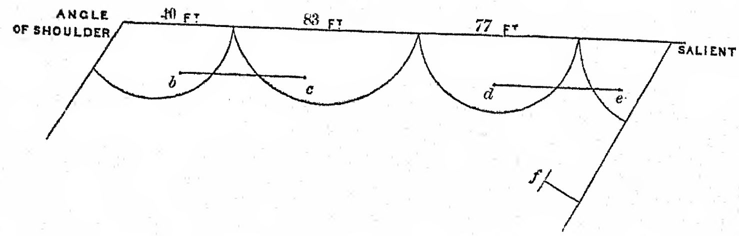
"In place of employing small charges, I have used large ones, having $n=2$ placed at the tails of the counterforts (fig. 24, Plate XV). In charging the mines at the salient, 19·43 (18 lbs.) were allowed for each 9·684 cubic yards (toise cube); for the faces 17·27 (16 lbs.) per toise were allowed, because the ground was of ordinary consistence. The volume of a common mine, with a line of least resistance of 22 feet 4 inches (21 feet French), is 784 cubic yards (81 cubic toises), which at 19·43 lbs. (18 lbs. French) per toise, will require a charge of 1578 lbs. (1462 lbs. French) for the salient, and 1404 lbs. (1300 lbs. French) for the faces: let these charges be augmented, not in the ratio of the cubes of the radii of rupture, as Belidor has proposed, but in that of the radii of the crater, which will increase the above computed charges to 3156 lbs. (2924 lbs. French) and 2808 lbs. (2600 lbs. French).

"The tamping was made in brick and in turf; the mines *b* and *d* were completely tamped, but the interior mines and that of the salient were not completely so, a space being left about the charge. (See Plate XV. fig. 24, and the following diagram *d*.)

COMPARATIVE TABLE OF RESULTS.

Explosion.	Indication of the Mine.	Charge for each mine. in lbs.	Force of the powder.	No. of cubic yards of empty space left.	No. of cubic inches of space left for each lb. of powder.	Volume raised in cubic yards.	Cubic yards raised per lb.	Relation of the effects produced by the mines.
1	Mine placed at the angle of the shoulder, 110°. *b*.	3156	26	,,	,,	4055	1·28	1·056812
	Mine marked *c*, in diagram *d*, in the left face.	2808	19	13·4	224	3727	1·32	1·092763
2	Mine *d*, in the same face.	2808	19	,,	,,	3413	1·21	1·000000
	Mine *e*, in the flanked angle, 77°.	3154	19	20·5	300	5232	1·65	1·321181
3	Mine *f*, placed in the right face.	3666	19	26·7	340	4578	1·25	1·020048

Diagram *d*.



29. "The examination of the breaches shews,—1st, That the part of the left face demolished by the mine *c*, which had a space left round the charge, was longer than that overthrown by the mine *d*, which had been completely tamped. 2ndly, That the mine at the flanked angle, where the space left round the charge had been increased, had overthrown the escarp 32 feet more than the mine at the angle of the shoulder, where the tamping had been completed. 3rdly, That the mine *f*, on the right face, having a greater space left round the charge than the mine *c* on the left face, had also demolished a greater length of escarp. By the Table already given, it is also manifest,—1st, That the total effect produced by the mine *c* on the left face, which had a space untamped in the vicinity of the charge, was greater than that produced by the explosion of the mine at the angle of the shoulder, charged with a greater quantity of powder and of a better quality. 2ndly, That the effect of the mine *f*, on the right face, is greater than that of the mine *d* of the left face, which had no space left round its charge, but smaller than that produced by the mine *c* of the same face, which had a less similar space left. 3rdly, That the mine at the flanked angle has produced an effect greater than any of the others.

30. "It is clear, then, that the space left around the charge is to a certain point advantageous, beyond which point it diminishes the explosive effect, but it has always the advantage of directing the greatest effect of the mine in the required direction.

"It has been observed in the experiments which have been made known, that in all mines where spaces or voids have been left around the charges, very little smoke has been observed after the explosion: the contrary generally takes place in the explosions where no space has been left. The smoke is mixed also with much flame, which is thrown out to a distance of 42 yards (20 toises). This fact evidently proves that in leaving no space round the charge in mines which are a little surcharged, a part of the powder is not ignited till after the explosion, or, at least, till after a great motion has taken place from the combustion of part of the powder, which must necessarily produce a diminished effect from the explosion of the whole.

31. "It has also been observed that mines placed in obtuse angles have produced a greater effect than when placed behind a straight revetment, and that mines placed in acute angles produce greater demolition than when placed in obtuse angles.

"Several methods of arriving at the mines were employed in the operations which have been detailed. The bastion had nearly the same perimeter as one which had been demolished with a minimum quantity of powder, employed in the usual manner by ordinary mines. In comparing the expense entailed by each method, by taking into consideration, on the one hand, that when large charges are employed, although a greater quantity of powder is consumed, yet a greater length of revetment is overthrown, and the material is broken up and divided;—on the other hand, the necessity, when ordinary charges are employed, to commence afresh, after overthrowing the

revetment, with a new series of demolitions, in order to break up again the masses of masonry, to make the material available for further use,—the earth it is necessary to bring, to produce the same effect, as regards the ascent of the breach, as when surcharged mines are used,—it will be found that if one-tenth in economy of powder be obtained by the ordinary mode of attack in demolitions, yet with surcharged mines is the advantage of a great saving of time; for in fifteen days as much can be done as can be effected in three months when the ordinary methods are employed, while very much labour is saved in executing the operations by the former methods.

CONCLUSION.

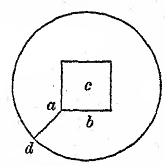
32. "After what has preceded, and, above all, after projects of demolition have been made under circumstances where walls of every variety of thickness and quality of masonry could be commanded, it may be enunciated as certain,—

1. That the maximum effect takes place when the space occupied by the powder is to the volume of space left around the charge in the ratio of 1 to 10, assuming that 1lb. occupies 27 cubic inches.

2. That the effect of a mine is more powerful in the direction in which the space is left than in any other, provided the ratio alluded to be not exceeded.

3. That with the same quantity of powder, placed under similar conditions, to destroy a straight wall, a salient, or a re-entering angle, the angles of demolition whose vertices are in the centre of the charge, and the sides tangent to the excavation, are in the relation of a; $a + 90$; $a - 90$; so that the maximum effect is in a salient angle, and the minimum in a re-entering angle; and by taking advantage of this principle, a tower has been breached without ruining a casemate which was within. If the charge had been placed at b, the casemate would have been destroyed: by placing it at a, two feet from the angle, it was preserved, although the line of least resistance $a\,d$ had a length of 11 feet.

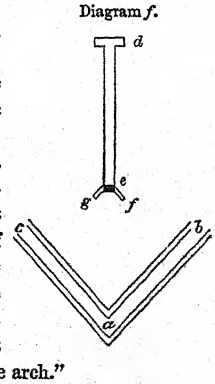
Diagram *e*.



"That it is necessary always to place the mines above the bottom of the ditch, or otherwise, if it be placed below that level, to remove the earth from the point of the foundation; that is to say, to dig a ditch in the ditch.

"Also, that if it be proposed to destroy two galleries, $a\,b$ and $a\,c$, after driving the gallery $d\,e$ for the necessary length, two small returns $e\,f$ and $e\,g$ should be added, which would be left empty, the charge being placed at e.

Diagram *f*.



"It appears, also, from experiment, that the less the tenacity and density of the soil, the greater should be the space left round the charge.

"Powder has been frequently employed in loose heaps, unconfined in boxes or chambers, particularly for the destruction of bridges, by placing a quantity along the summit of the extrados of the arch; but the Chief of Battalion of Engineers, Breuille, an Officer distinguished for his knowledge of mining, states, that by placing the charge under the arch, the demolition will be more complete: he proposes simply to place the powder in a small case, and suspend it from above, the case being brought close to the soffit of the arch."

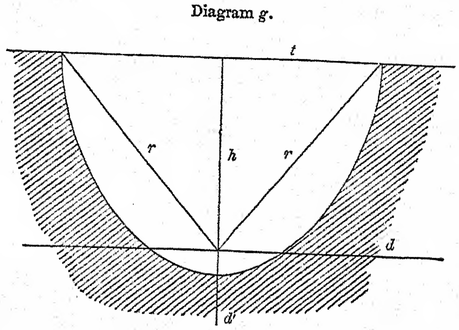
He states also, that 150 lbs. of powder, placed against a wall, destroyed 25 feet of it. The thickness is not given.

Formulæ for the Charges of Mines.

33. If h represent the line of least resistance of a mine; t, the radius of its crater; r, its radius of explosion; d, its horizontal radius of rupture; and d', its vertical radius of rupture; let $\frac{t}{h} = n$. The mine is called an ordinary or common mine when $t = h$ or $n = 1$. It is said to be surcharged when t is greater than h, or n is greater than 1; and undercharged when t is less than h, or n is less than 1.

Common Mines.—Let c represent the charge in lbs. of an ordinary mine, the powder having a density of 0·91, placed in ground of average density and tenacity, that is, requiring about 1·337 lbs. of powder to raise a cubic yard; c' the charge of a surcharged mine; and $c_{,}$ that of an undercharged mine: also, let $b, b', b_{,}$ represent the sides of a cubical box capable of containing the charges $c, c', c_{,}$; then there will result $c = 1687{\cdot}5\, b^3 \times 0{\cdot}91$: representing by the small letters the elements of one mine, and by large letters those which belong to a second,—equations or proportions are obtained as follows:

Diagram g.



$$(2). \quad \frac{c}{C} = \frac{h^3}{H^3} = \frac{t^3}{T^3} = \frac{r^3}{R^3}.$$

Performing the same operation in the different formulæ recapitulated at page 75 of the 'Manual for Practical Miners,' two series of formulæ, as given below, will be obtained, of which the first is that of the miner in terms of c and of h^3: the second contains only simple terms of b and h.

Mines.	Common mine, $n = 1$.	(3). $C = \frac{11}{6} h^3\, 1{\cdot}337 = 2{\cdot}451\, h^3$.	(3′) $b = \frac{h}{8{\cdot}55}$.
	Surcharged from $n = 1$ to $n = 3$	(4). $C' = C\,(0{\cdot}15 + 0{\cdot}85\, n)^3$.	(4′) $b' = b\,(0{\cdot}15 + 0{\cdot}85\, n)$.
	Surcharged from $n = 1$ to $n = 5$	(5). $C' = 2{\cdot}451\, T^3 (1{\cdot}05 - 1{\cdot}05 n)^3$	(5′) $b' = \frac{T}{8{\cdot}55}(1{\cdot}05 - 0{\cdot}05\, n)$.
	Surcharged from $n = 1$ to $n = 1{\cdot}5$	(6). $C' = 2{\cdot}451\, T^3$.	(6′) $b' = \frac{T}{8{\cdot}55}$.
	Undercharged, when n less than 1,	(7). $C_{,} = C\left(\frac{4 + 3n}{7}\right)^3$	(7) $b_{,} = b\, \frac{4 + 3\, n}{7}$.
	Common, overcharged, and undercharged,	Radius of rupture: Horizontal (8) $d = \frac{7}{4} h$	(8′) $b = \frac{1}{15} d$.
		Radius of rupture: Vertical (9) $d' = 1{\cdot}41\, h$	(9′) $b = \frac{1}{12} d'$.
Camouflets.	Maximum at a distance h from the gallery,	(10) $C = C\,(\frac{4}{7})^3 = 0{\cdot}45\, h^3$.	(10′) $b = \frac{1}{15} h$.
	Maximum against a gallery situated at a distance d on the same level,	(11) $C' = 2{\cdot}451\, d^3 (\frac{4}{7})^3 = 0{\cdot}45\, d^3$.	(11′) $b = \frac{1}{15} d$.
	The same at distance d', vertically below	(12) $C = 2{\cdot}451\, d'^3 \left(\frac{1}{\sqrt{2}}\right)^3 = 0{\cdot}86\, d^3$	(12′) $b = \frac{1}{12} d$.

Note.—In these equations the charge is in lbs.; b is supposed to be expressed in yards. C denotes common mine; C′, overcharged; $C_{,}$, undercharged; b, side of box in common mine; b', ditto overcharged; $b_{,,}$ ditto undercharged.

Table *shewing the Charges in Soil of different Natures compared with ordinary Earth, or the Co-efficient of* c; *as also the corresponding Dimensions of the Powder-box, or the Co-efficient of* b.

NATURE OF SOIL.	Density.	Co-efficient of *c*.	Co-efficient of *b*.
Argillaceous soil mixed with sand or gravel, called in French, ordinary earth	1·88	1·00	1·000
Common earth (*terre commune*)	1·37	1·12	1·038
Sand	1·79	1·25	1·079
Damp or wet sand	1·91	1·31	1·092
Earth mixed with small stones	1·92	1·41	1·120
Clay mixed with loam	2·01	1·55	1·157
Argillaceous earth mixed with flints	2·31	1·69	1·190
Rock	2·31	2·25	1·310
New or old masonry in a damp condition, not cemented by hydraulic lime	2·31	1·30	1·090
Common masonry	2·31	1·66	1·183
Very good new masonry	2·31	2·25	1·310
Masonry in Roman cement	2·31	2·90	1·425
Good masonry, when disposed vertically, as in revetments	2·31	0·83	0·910

The formulæ 7, 12: all the formulæ in terms of b are taken from an unpublished Memoir, which, however, has received the approval of the Committee of Fortification. They tend much to simplify the calculations for the charges of mines fired under various conditions of media. In the same memoir the two following theorems are enunciated, viz.

1. For the same charge, the common mine is that the volume of which is a maximum.

2. For the same charge, the surcharged mine, in which $n = 2$, is that which produces the greatest surface effect.

Note.—In giving this Memoir of a Committee of Engineer Officers in the French Service, and the rules laid down and formulæ adopted, it is not intended that they should supersede the valuable information collected under the article 'Demolition' in this work, and more particularly in Table VI. of that article.—*Editors.*

APPENDIX III.—VENTILATION.*

Great attention must be paid to ventilation in driving extensive galleries, as the gas generated by explosions of gunpowder, or contained in the soil, collecting, particularly in ascending and descending portions, has sometimes suffocated the miner before the extinction of his light has warned him of its presence; and even under ordinary circumstances, the air becomes so much vitiated by the presence of the workmen alone, that branches cannot be safely driven more than about 60 feet: apertures should therefore be bored, if possible, up to the surface of the ground, at intervals beyond that distance, taking care to conceal their position from the enemy, if possible; and communications may be made with adjacent galleries to create a draught.

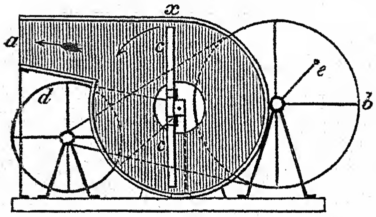
Mechanical means are also required for producing a circulation of air, so as to substitute fresh air for that which is impure: for this purpose tubes are fixed, through which fresh air may be forced in or bad air extracted; but as there may be a large quantity of noxious gas in the soil, ready to supply the place of that extracted, the system of *forcing in* fresh air has generally been preferred in military mining.

The tubes used for ventilation have been constructed of iron, but gutta-percha or vulcanized Indian rubber would probably form better materials for them.

* By Captain Bainbrigge, R. E.

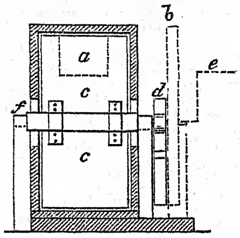
A cylindrical bellows has been used for forcing in the air, but this has proved inefficient; and as the French and Germans use fanning machines for that purpose, it is probable that they may be employed with advantage for ventilating extensive galleries: therefore a sketch of one lately made by Sergeant Lewis, Royal Sappers and Miners, is here given (figs. 1 and 2), with some modifications required to render it efficient. The pipe for conveying the air from *a* should be at least 6 inches in diameter, and should be attached to the top of the gallery, and the box in which the fans revolve may be made of wood or sheet iron; it has only two fans, formed by a single board *c c*, experience having proved that a greater number do not increase the power: the axle to which it is attached is turned by a strap (shewn by dotted lines) passing round the tire of the wheel *d*, the axle of which is turned by another strap passing round the tire of the wheel *b*, which is worked by the handle *e*: thus the air in the box is made to acquire a centrifugal motion, and passes rapidly out of the exit pipe *a*. By attaching the tubes to the aperture *f* (fig. 2), and closing the opposite one, the bad air could probably be *drawn out* of the gallery and driven away at *a* in the same way, if that be preferred; and the size of the machine may be increased, or additional ones applied, if more power be required.

Fig. 1.



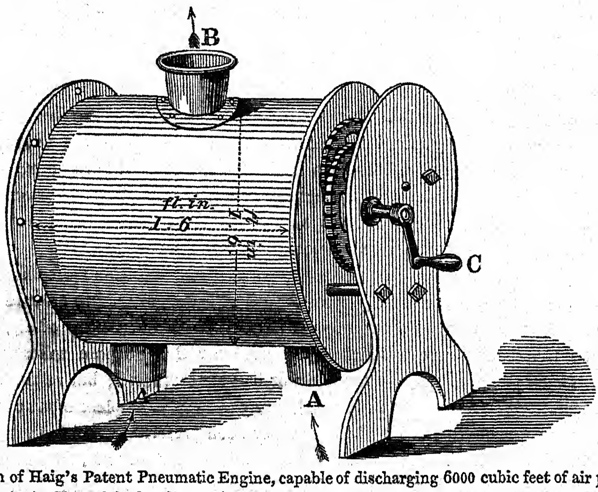
Longitudinal Section, (scale 2 feet to an inch.)

Fig. 2.



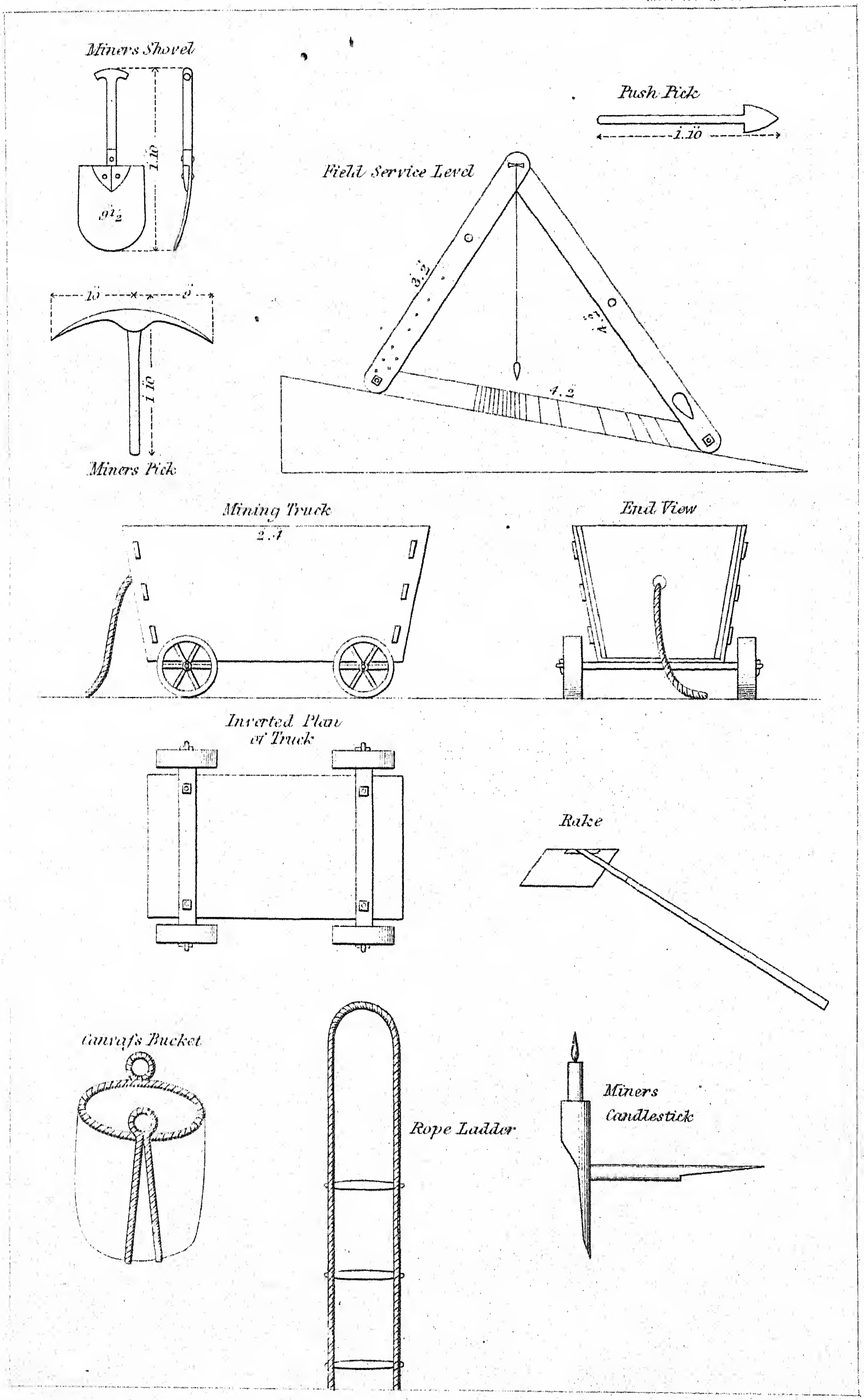
Section at *x*.

Note.—As in many cases it may be found desirable to *exhaust the foul air* in a military mine, the following description of Mr. Haig's patent pneumatic engine, invented for the purpose of purifying the holds of vessels, is here inserted.—*Editors.*



Elevation of Haig's Patent Pneumatic Engine, capable of discharging 6000 cubic feet of air per hour.

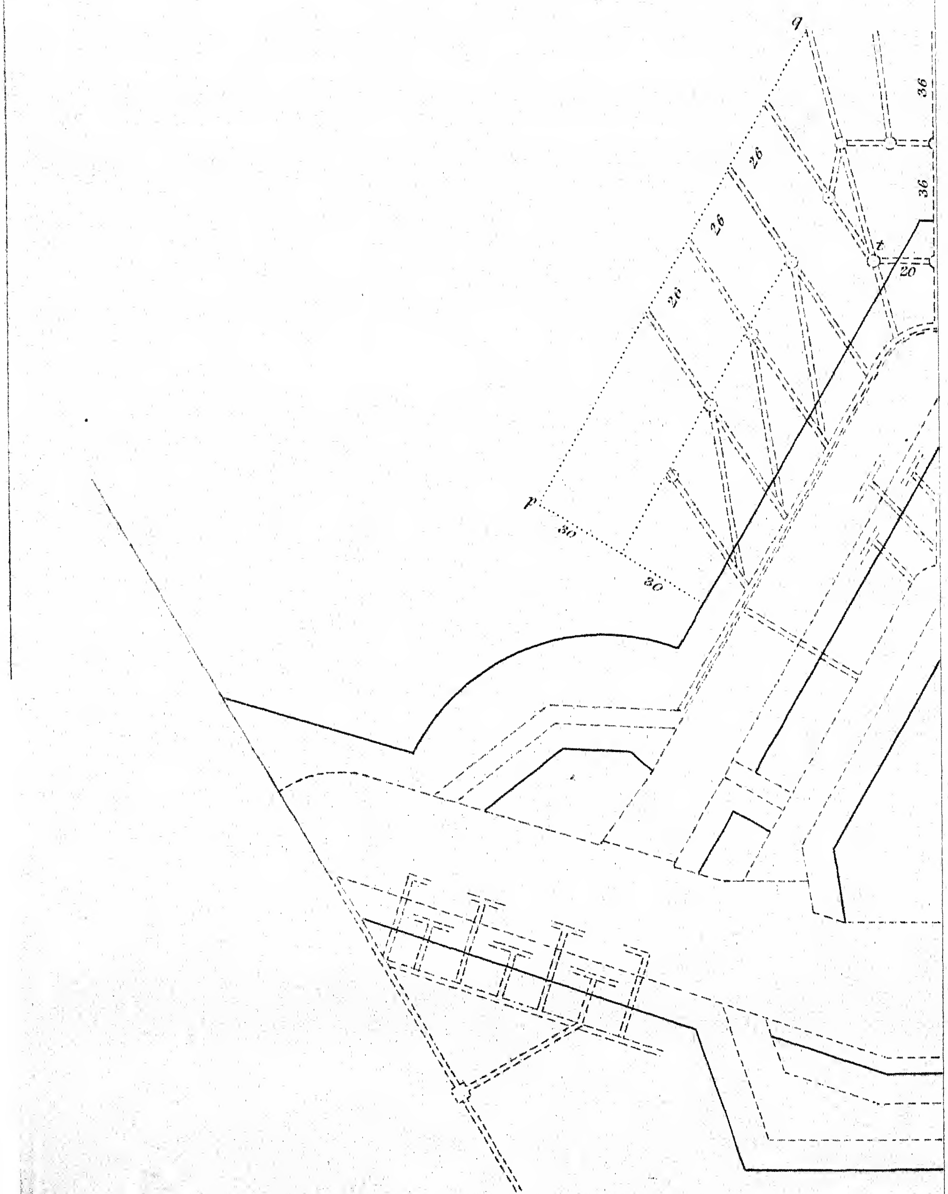
A, A. Two 3½-inch exhaust pipes. } These pipes may be extended as required.
B. 3½-inch delivery pipe.
C. 5-inch winch or handle.



J. W. Lowry fc.

London, John Weale 1849.

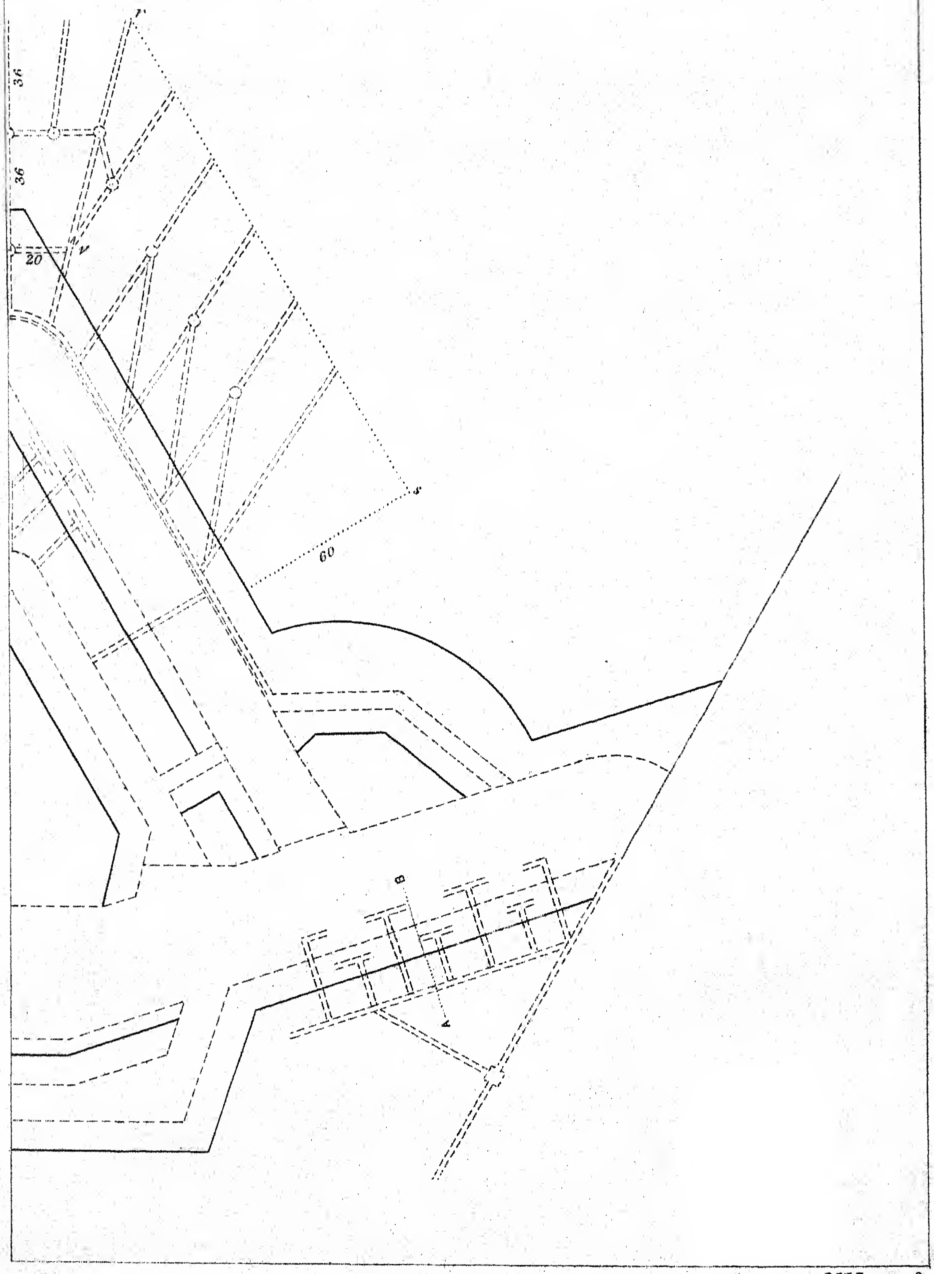
DUFOURS SYSTEM OF COUNTERMINES.



Scale One Inch = 60 Yards

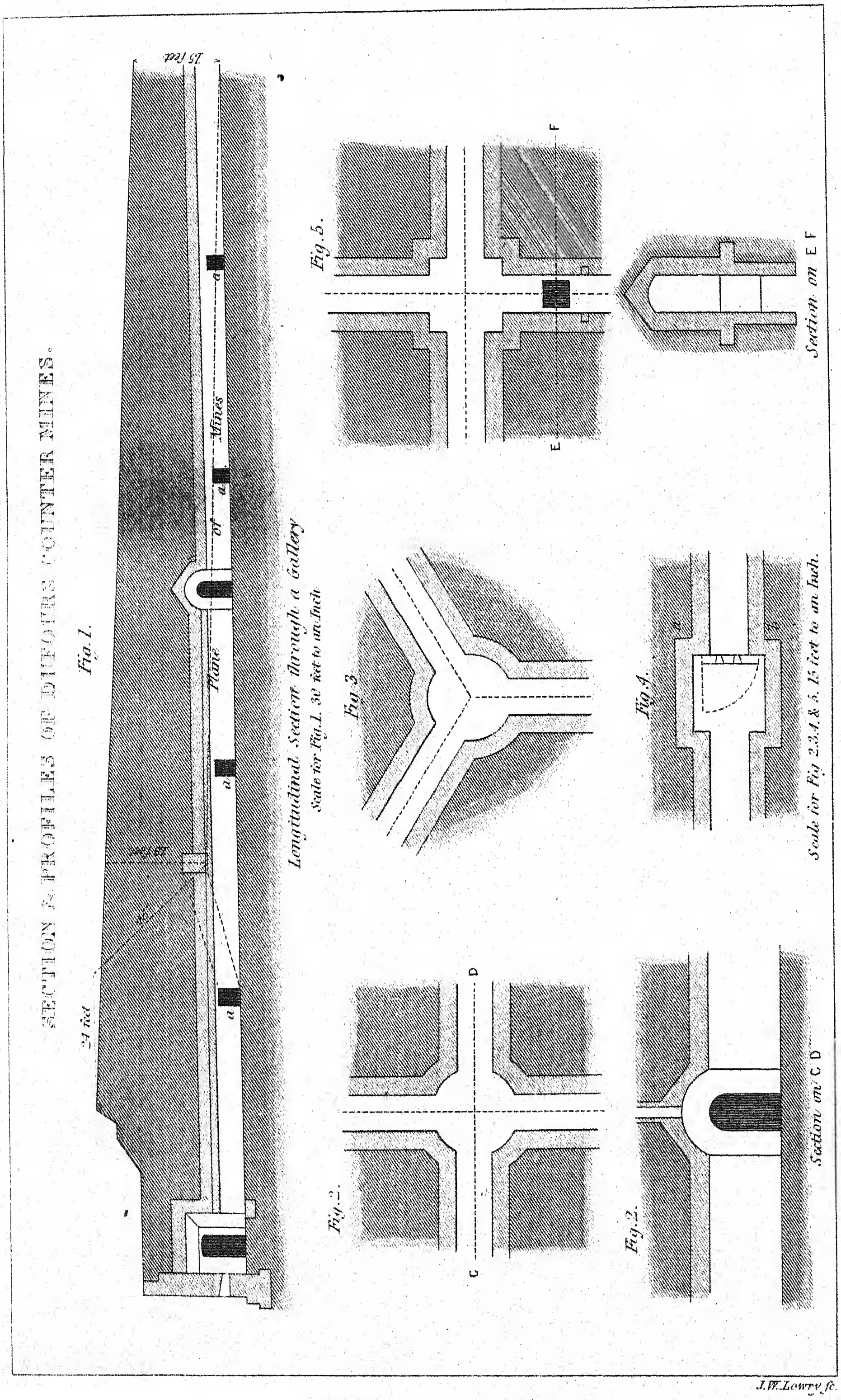
London, John Weale, 1849.

Mem. The dotted Lines represent the Masonry on the Level of the Countermines.



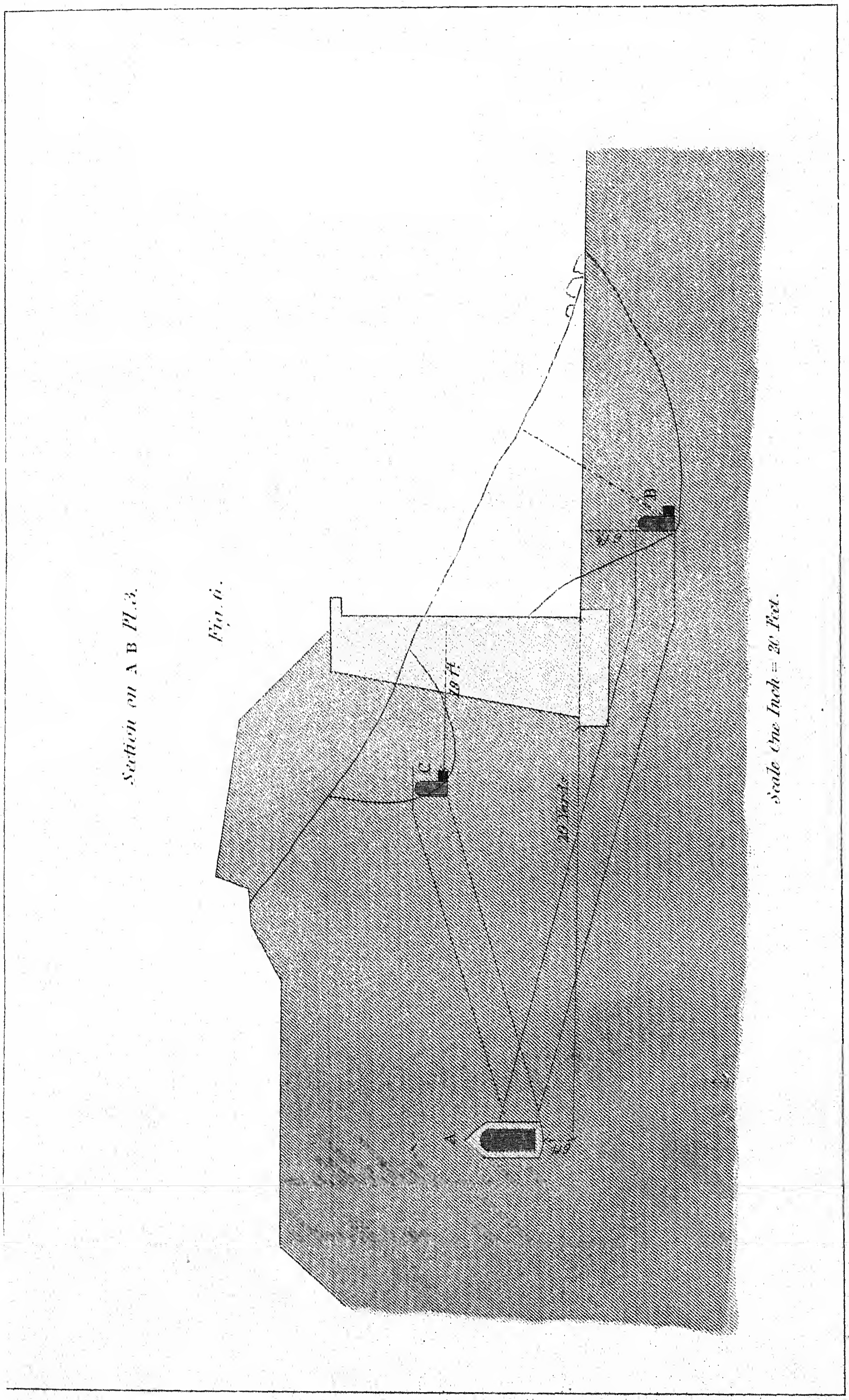
J. W. Lowry fc.

London, John Weale 1849.



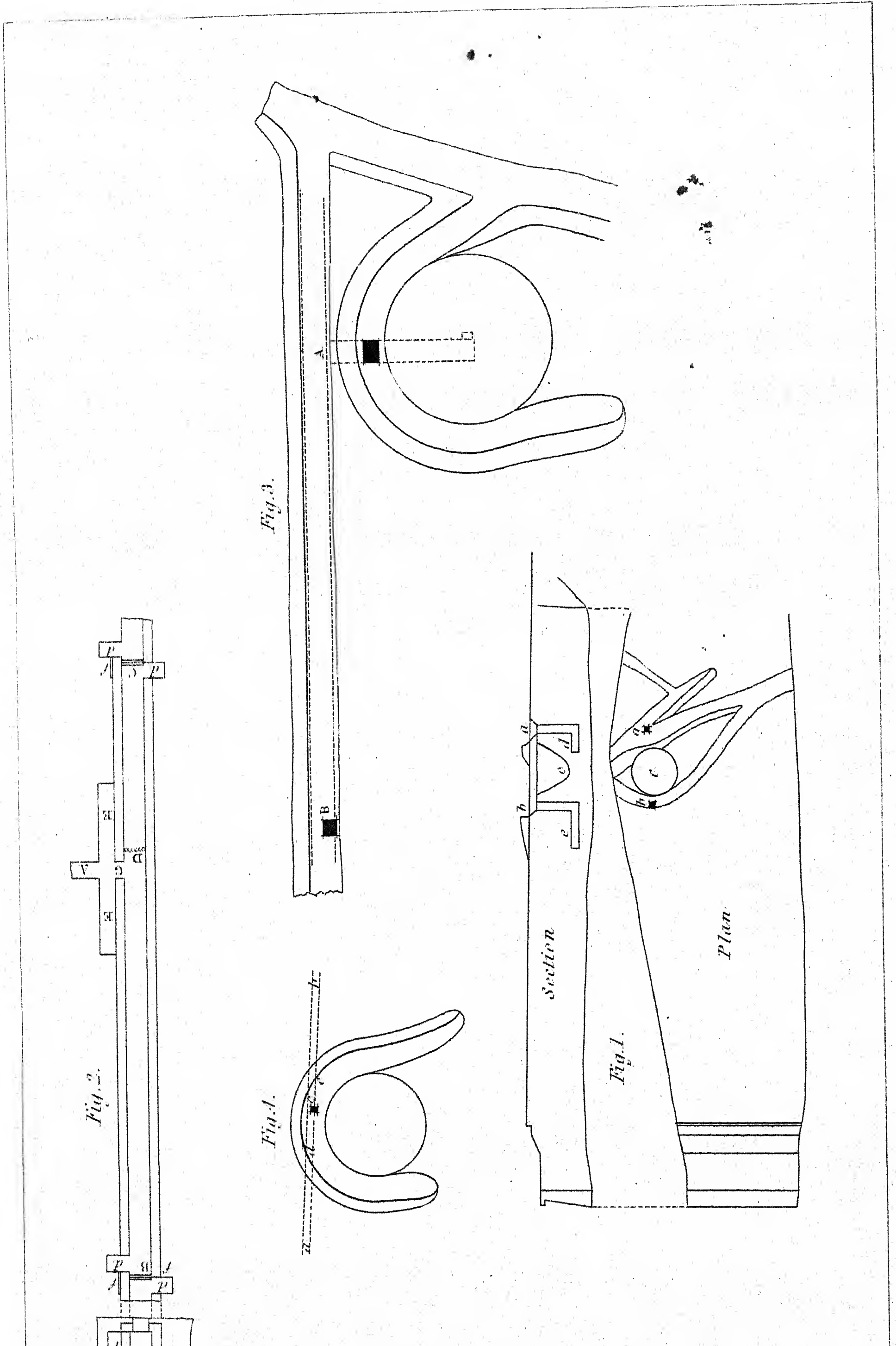
J. W. Lowry fc.

John Weale 59 High Holborn 1849.



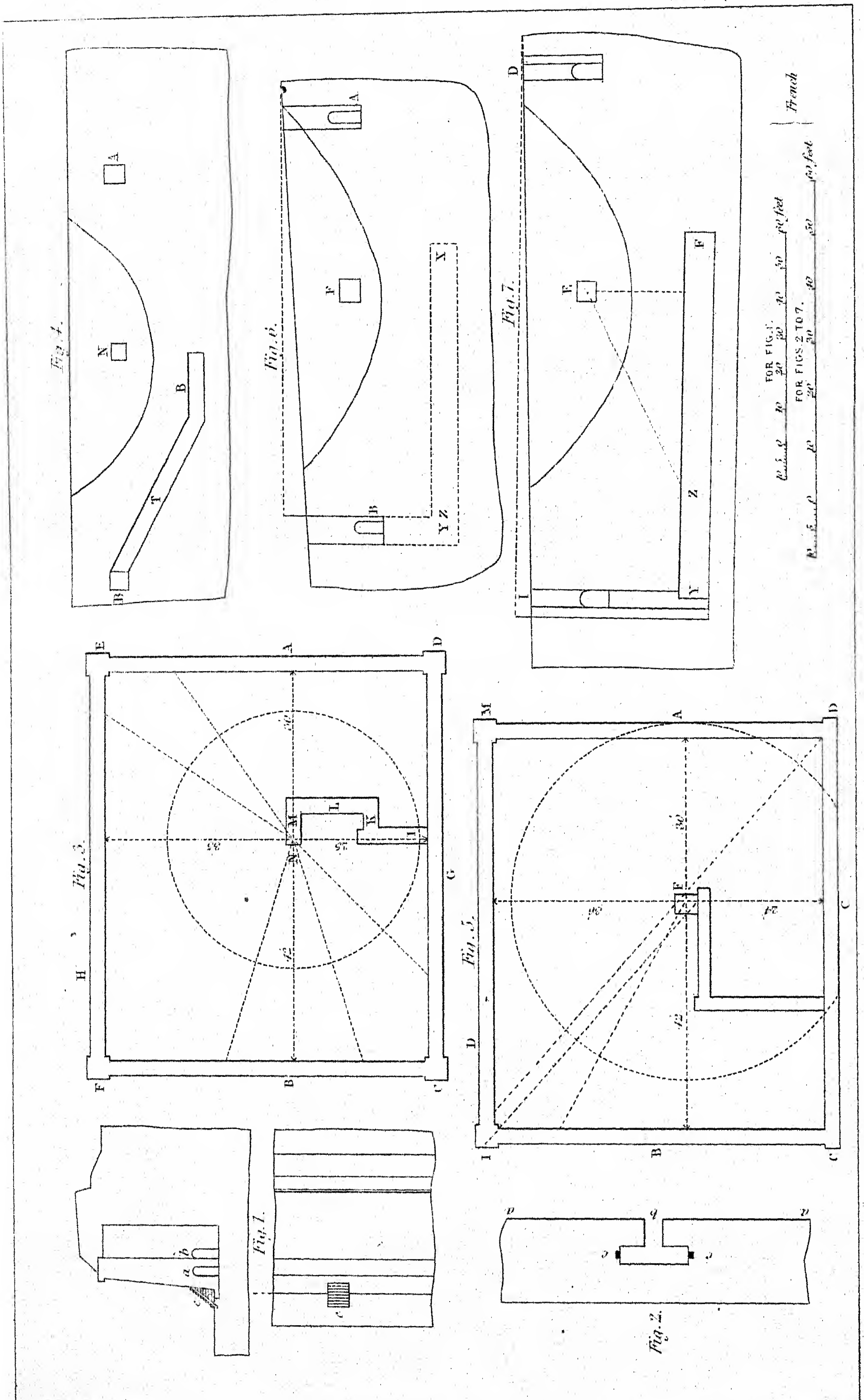
J.W. Lowry fc.

London, John Weale, 59, High Holborn, 1849.



J. C. del[t] L[t] R.E. J. W. Lowry fc.

John Weale, 59, High Holborn 1849.

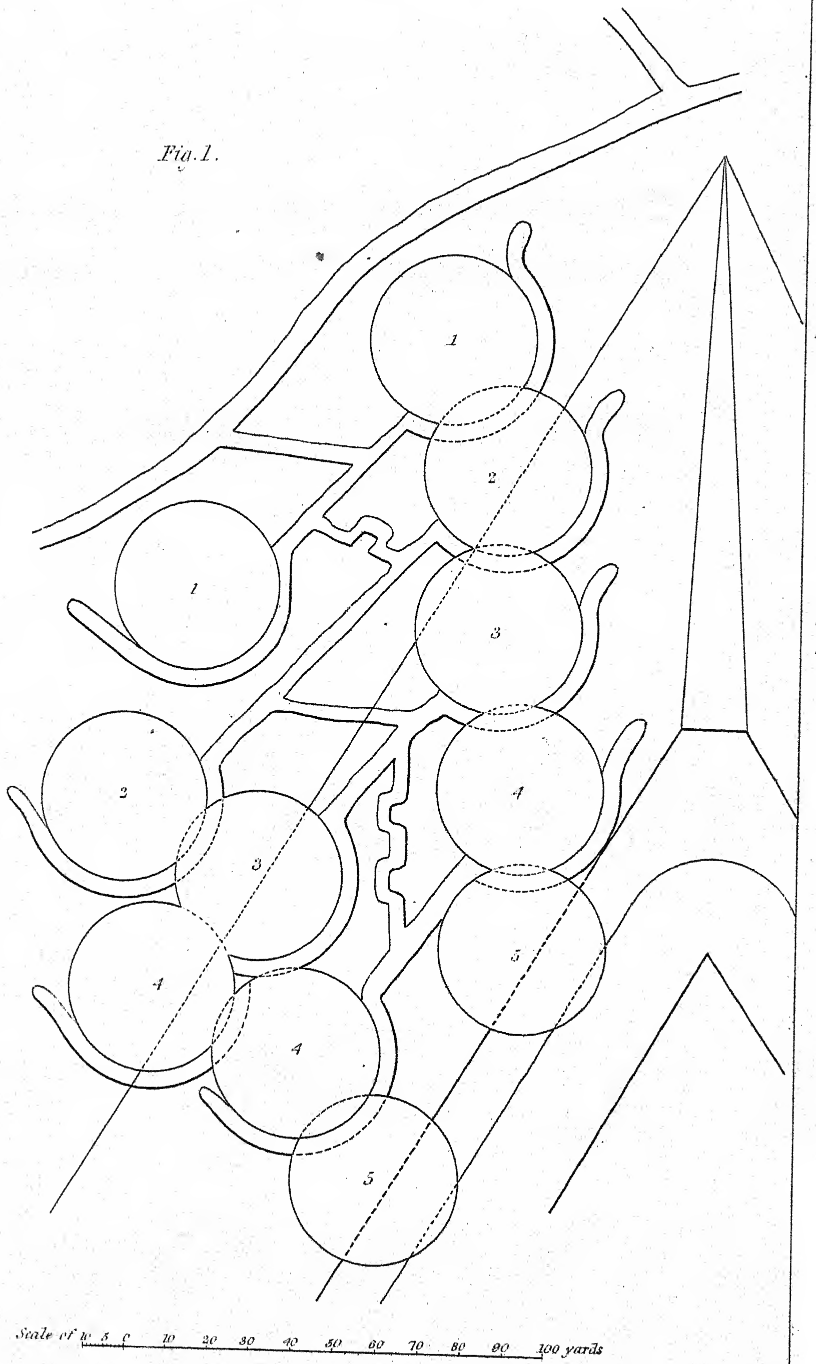


J.C. delt. Lt. R.E.

J.W. Lowry fc.

John Weale, 59, High Holborn 1849.

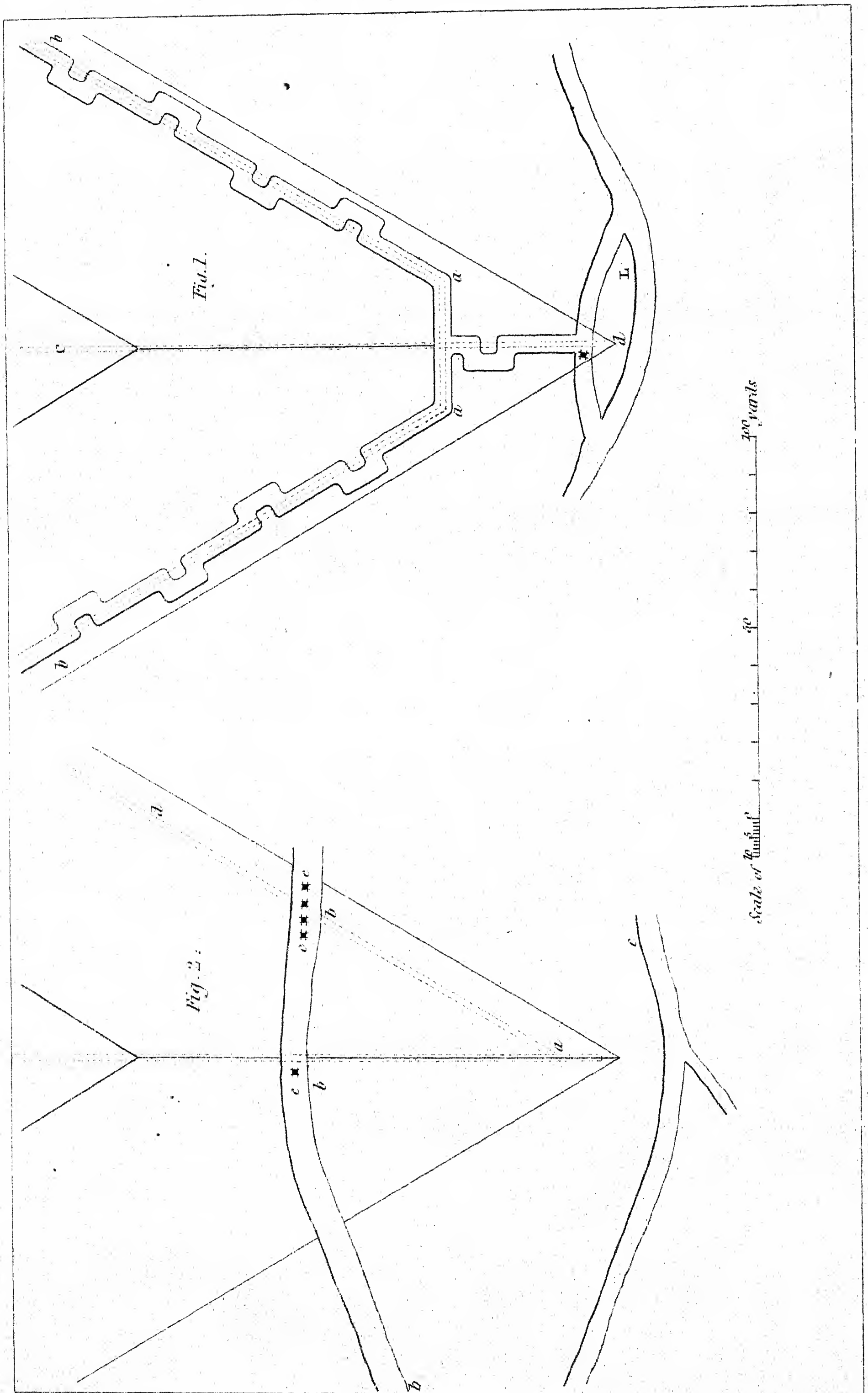
Fig. 1.



J. C. De B. Lt R.E.

J. W. Lowry sc.

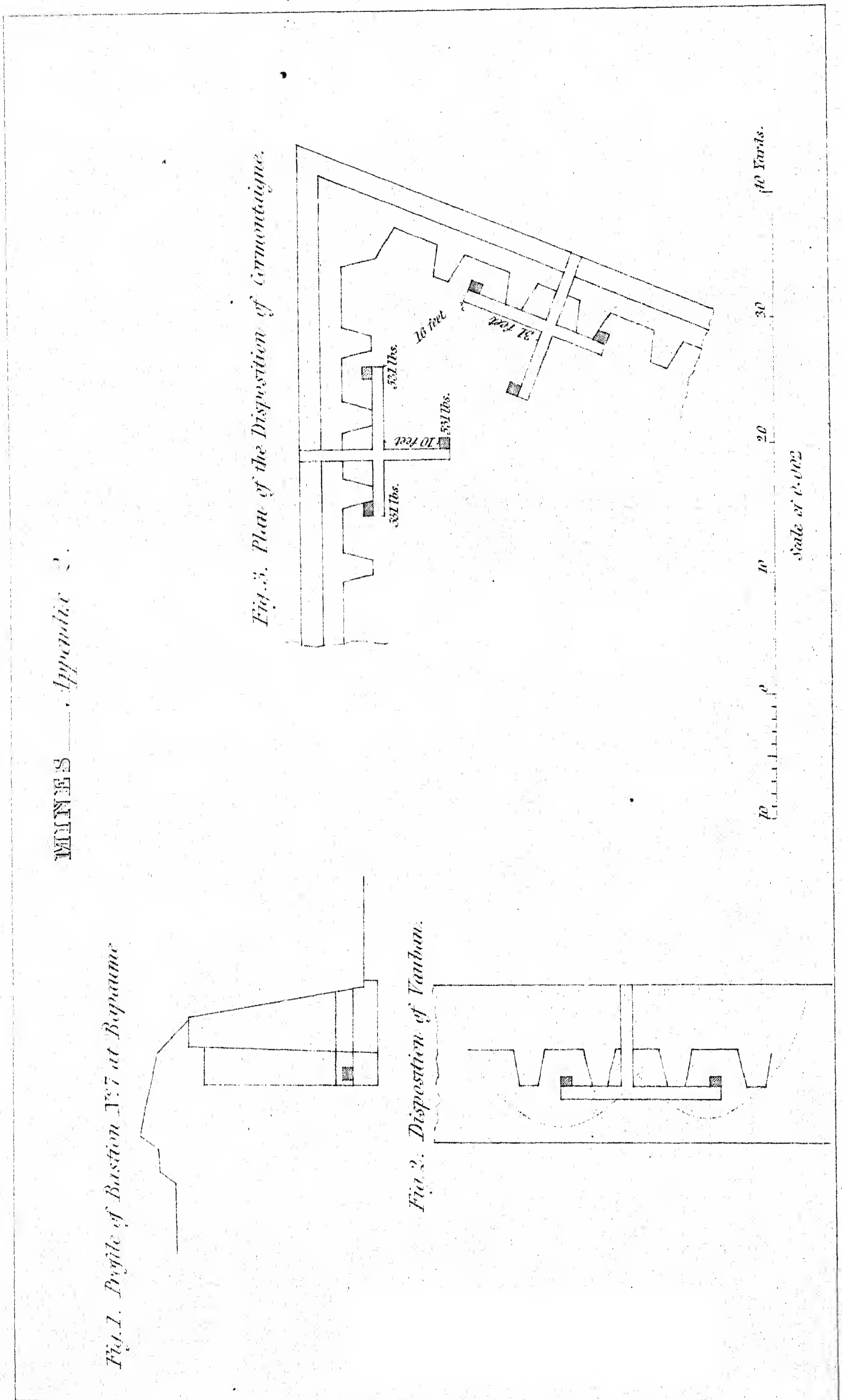
John Weale 59 High Holborn 1849.



J.C. De B. Lt. R.E.

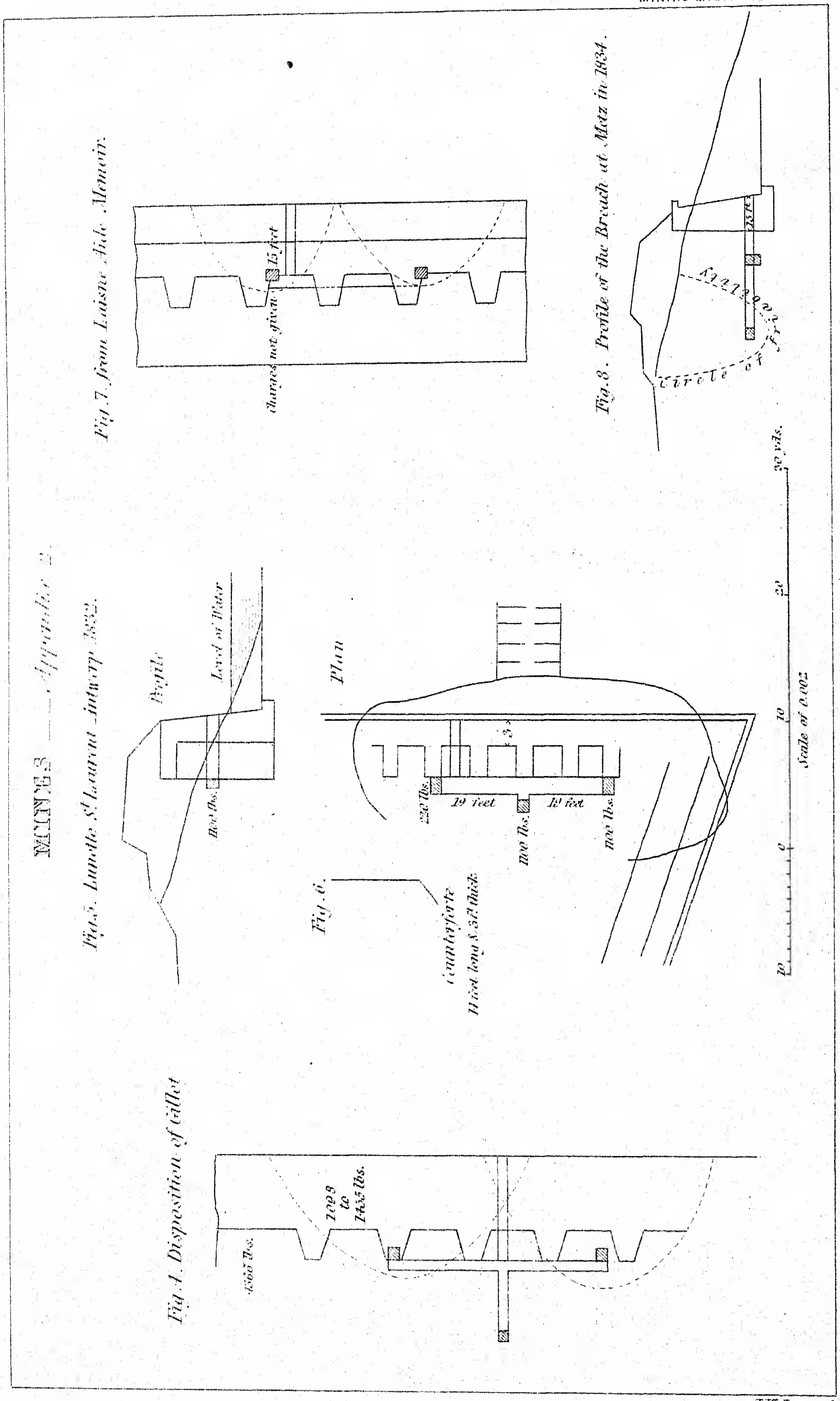
J.W. Lowry fc.

John Weale 59 High Holborn 1849.



J.W. Lowry fc.

John Weale, 59, High Holborn, 1849.



J.W. Lowry fc.

John Weale. 59. High Holborn 1849.

MINES — Appendix 2.

Fig. 9.

Plan of Breach at Metz in 1834.

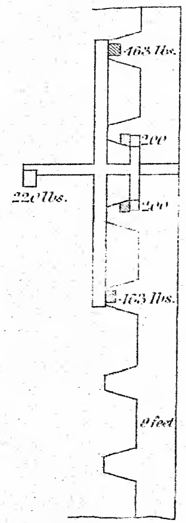


Fig. 10'.

Breach in C'scarp Montpellier in 1833

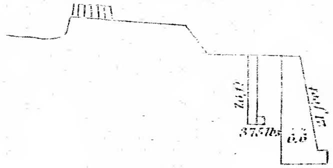


Fig. 11.

Project of the School at Arras in 1847.

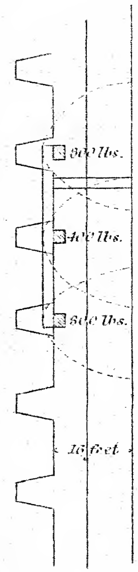
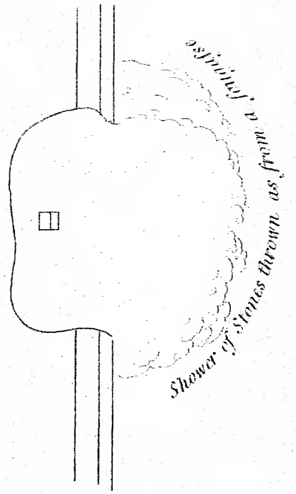


Fig. 10.

Plan



10 0 10 20 30 Yards.

Scale of 0.002

W. J. Lowry fc.

John Weale, 59, High Holborn 1840

MINES . Appendix 2.

Fig. 12. Demolition of Turin.

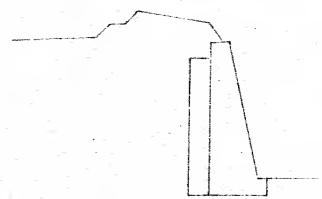


Fig. 12. Plan.

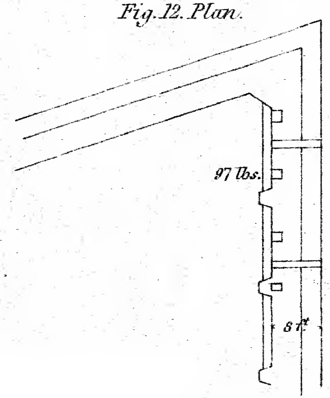
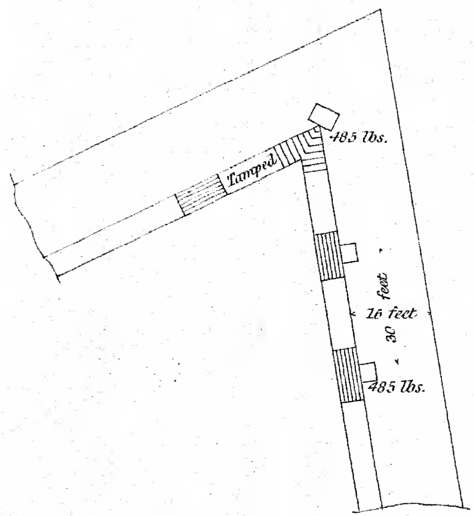


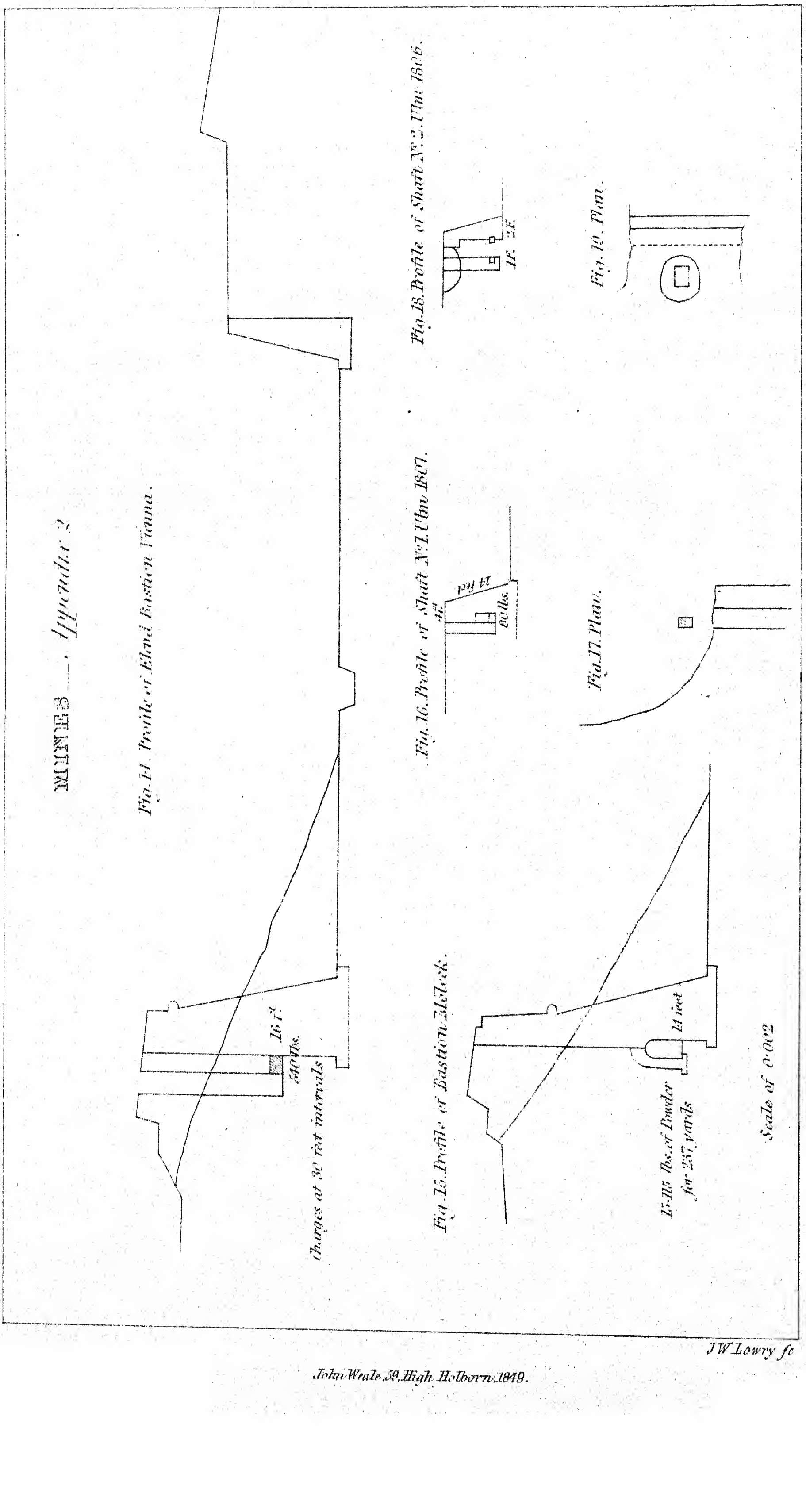
Fig. 13. Demolition of Verona.



Scale of 0·002

J. W. Lowry fc.

John Weale, 59, High Holborn, 1849.



J W Lowry fc

John Weale, 59, High Holborn, 1849.

MINES. Appendix 2.

Fig. 20. Profile of Bastion, Burg, Vienna, 1807.

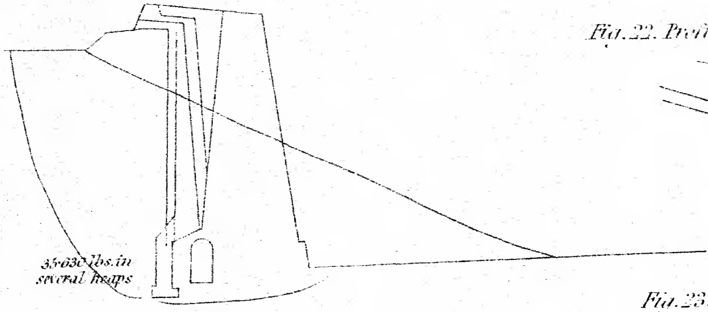


Fig. 21. Plan of Bastion for 320 Yards.

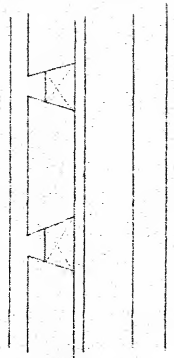


Fig. 22. Profile of C'scarp at Metz 1834.

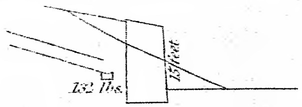


Fig. 23. Plan of C'scarp.

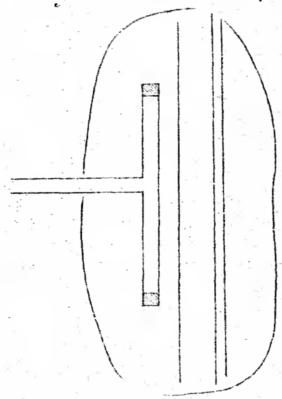


Fig. 24. Plan of the Experiment reported by Genl. Chafseloup.

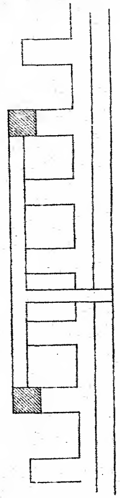
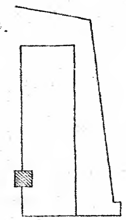


Fig. 25. Profile.



Scale of 002.

J. W. Lowry fc.

London, John Weale 59 High Holborn 1849.

"The want of an efficient mode of ventilation has long been seriously felt, particularly in the Navy, and large Public Buildings: many plans for obviating this great evil have been suggested, and large sums expended in attempting to bring them into practice. They have, however, been found either too costly, or incapable of accomplishing the object for which they were designed.

"The importance of a free circulation of atmosphere in all places where we have to exist is so well known and admitted, and so much has been said and written upon the subject by scientific and medical men, that it is unnecessary here to detail the baneful effects that ensue from inhaling contaminated atmosphere.

"In bringing forward a means by which this object can be obtained, the inventor feels satisfied, that as soon as his method becomes known, from its simplicity of construction, and moderate cost, it will be universally adopted in all places requiring the aid of artificial means to keep up a constant current of wholesome air. The fact of its having been successfully applied in the ship 'Sylph,' and also in the 'Rosamond' steam ship, is a sufficient guarantee to warrant the inventor in coming to this conclusion.

"From a series of experiments recently made at the patentee's manufactory on the power of a machine 1 foot 6 inches in diameter, constructed upon his plan, it was found that nearly 6000 cubic feet of air could be removed under the ordinary pressure in an hour. If, therefore, it were required to ventilate a vessel of 1000 tons (which is about the size of the 'Rosamond'), it would be found that the fore-part contains about 21,815 cubic feet, the middle or engine-room 36,040 feet, the after-part 12,000 feet, making a total of 69,855 cubic feet: supposing half of this space to be occupied with stowage, the other half, or 34,927 cubic feet of air, has to be removed, which might be done in an hour with seven machines of the size of the one above described; but if it were required to be done in less time, this might be readily effected by increasing the size of the machine, or making use of a greater number."

MOUNTAIN ARTILLERY.*—Various opinions have been entertained on the subject of Mountain Artillery and the service it is capable of rendering to an army. By some, the lighter guns usually employed, and especially those carried on mules, have been considered to be utterly worthless; by others, their value has been overrated. It cannot for a moment be supposed that any such artillery, in any possible number, can be compared in effect with good Field Batteries capable of overcoming all the ordinary difficulties of ground; but in the mountains, excepting in the immediate vicinity of the great roads which traverse them, the best equipped field artillery is liable to become paralyzed by obstacles that it cannot master, and to be rendered not only useless, but a cause of serious embarrassment to the troops to whom it is attached. And the question then arises, whether for a part of the services which artillery can render, and in the particular circumstances which present themselves in mountain warfare, guns of lighter weight, and those even which admit of being carried on mules, may not be employed with effect.

The solution of this question is obviously dependent on the nature of the country and of the difficulties it presents, and is therefore one of degree,—of which the conditions may be thus stated, it being premised that in the observations which follow, it is not proposed to enter on the subject of the *Passage of Mountains* by field or heavy artillery,—an operation of much interest, but which does not belong to the

* By Lieut.-Col. Colquhoun, Royal Artillery.

subject; for under such circumstances, the gun and its appurtenances become mere articles of transport, and all their powers dormant for the time. An example of this operation, the most brilliant that history presents, and that well deserves to be studied in all its details, is that of the passage of the Alps by the Grand St. Bernard, by Napoleon, in May, 1800.*

Whenever the operations of an army are to be conducted in a country so mountainous and broken as to render it difficult or impracticable for ordinary field artillery to accompany the march and support the movements of the troops, recourse must be had to guns of less weight, and to lighter loads of ammunition, than those usually employed; and it may be necessary that the number of guns, in proportion to the troops, should be reduced also. This first degree of change is that which is required when the country is still of a character to permit the use of wheel carriages by the inhabitants, for in that case roads of some kind will be found to exist; and under such circumstances, provided that these roads are sufficiently numerous and practicable, the changes of equipment may be limited,—firstly, to the employment of ordnance not exceeding in weight 6 cwt., with corresponding loads of ammunition; and, secondly, to the reduction of the track of the wheels to a dimension within that of the country,† and of their height to a quantity that does not materially exceed the track. It will be necessary also that the draught be arranged to be readily made single or double, as required, and that draught mules with horse leaders should, if possible, be provided.‡

Under circumstances of sudden or expeditionary service, in a difficult country, but not wholly impassable to artillery, it may sometimes be convenient to convey the guns only upon wheels, and to carry the whole of the ammunition, excepting that on the limber (if the latter be not also dispensed with), on pack-saddles. This would require nearly twice the number of cattle necessary to transport the same quantity in draught, but the equipment would be much more moveable, and able to master far greater difficulties than if the ammunition were carried on wheels.§

If, however, the country in which the operations are to be conducted be really mountainous, the roads practicable for any kind of carriage will be few and difficult,

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* *Vide* Gassendi, 'Aide-Mémoire de l'Artillerie,' 1819, p. 265; and Thiers, 'Histoire du Consulât et de l'Empire,' Book iv.

† In most of the mountainous countries of Europe, the track of the country roads is from 3 feet 6 inches to 4 feet 8 inches.

‡ Such light batteries on a narrow track were employed by the British artillery in the early campaigns of the Peninsula on the frontier of Portugal; and the Service possesses, besides the light 3-pounders of 4 feet for colonial service, two descriptions of carriages for light 6-pounder and 12-pounder howitzers for the use of the Navy when acting on shore; in one of which the track (measured from out to out) is 4 feet 2 inches, and the wheel in height the same: in the other, for 12-pounder howitzers, now the established pattern, the track is 3 feet 8 inches, and the wheel 3 feet 6 inches. Spain possesses 4-pounder field batteries, constructed for narrow mountainous roads (*à carril estrecho*), with mules in double draught, that are capable of good service; and France had formerly similar equipments also; but since the rejection of the calibres of 4 and 6 pounders from her system, and the adoption of the mountain howitzer, properly so called, carried on mules, they have been entirely disused. For a detail of the various arrangements in the French Service for guns and carriages on narrow tracks or sledges, or other means of conveyance by men or cattle, which preceded in France the present system of Mountain Artillery, see Gassendi, 'Aide-Mémoire,' 1819, p. 303; and for a notice of the gradual progress by which the organization now established was arrived at, 'Journal des Armes Spéciales,' 1842, ix. p. 397.

§ The Austrian Horse Artillery formerly carried a part of their ammunition (80 rounds per gun for 6-pounders) on pack-horses. *Vide* Scharnhorst, 'Handbuch der Artillerie,' 1806, II. 300 and 547. The limber boxes of the 12-pounder field howitzer for Naval Service are fitted to be carried on the pack-saddle, when required.

easily rendered impassable, and the movements of an army to which an artillery, modified even as above stated, may be attached, will be liable to be continually restricted and impeded by the embarrassment that it must of necessity occasion. Under the condition, then, of a country really mountainous, and when the question is that of operations, whether of attack or defence, and not merely of passage, all transport upon wheels must be abandoned, and the mule and pack-saddle become the resource of the artillery; the condition under which the weight of the guns to be carried, and all other loads of ammunition or equipment, being the capacity of that animal as a beast of burden, keeping pace with infantry in difficult ground. This may be considered to be at the maximum 280 lbs. exclusive of the pack-saddle. The mules for the service of mountain artillery should not exceed in height $14\frac{1}{2}$ to 15 hands, and should not be taken from a level country, but, on the contrary, should have been accustomed to all the difficulties of mountain paths.

It is under such circumstances that the distinctive character of mountain artillery, properly so called, has its origin; and if, on the one hand, it should appear that the power of the arm is reduced, its mobility and ready application are entirely restored, and its quantity may be increased to any proportion that is thought fit: it need occasion no embarrassment whatever; for wherever troops can act, mountain artillery, properly equipped, may accompany them, and may make up, by its power of concentration and the mass of fire it may be employed to throw on the few points of operation that occur in mountain warfare, for its comparative inferiority of individual effect. For let it be remembered, supposing howitzers to be employed, and the calibre not to be less than 12-pounders, that apart from the consideration of the force of the blow of the projectile, which, however, is sufficient to destroy men and horses, the splinters of the shells have the same effect, whatever be the weight of the ordnance they are discharged from, and whether that be $2\frac{1}{4}$ or 10 cwt.

It is necessary to observe, that the same conditions which present themselves to modify the equipments and service of the artillery in a mountainous country, produce also their effect on the system and character of the operations of the army. Not field artillery only, but cavalry also, are rendered almost wholly useless,—the order of the infantry changes, and becomes less dense,—positions, in general, less continuous,—and attacks in mass are replaced by others dependent on each other, and successive, but in smaller force;—surprises, the attack and defence of defiles, and movements by a flank, become frequent, and the whole character of the operations changes with that of the ground. To this change there is no reason that a mountain artillery, well organized, may not adapt itself with undoubted advantage: its function will, it is true, be considerably altered, but services of great importance will remain to it, provided that it be well equipped,—that it be rendered as moveable as the troops themselves,—that it never becomes a cause of impediment or delay,—and that its fire be capable of concentration in quantity, when required.

In times past, the guns that from an early date were employed in Europe in mountain warfare, were carried upon mules, and consisted generally of 1 and 2 to 4-pounders inclusive, to which sometimes were added wall-pieces, and at a later period howitzers and mortars of reduced weight. More recently, by a change that seems to have obtained general consent throughout Europe, the small round-shot guns have been wholly abandoned, and have been replaced by light howitzers of 12-pounder calibre, formed into batteries regularly organized, and consisting usually of six pieces.

The mountain guns of the Duke of Wellington's army, which entered the Pyrenees in 1813, consisted of 4-pounders, and were Spanish guns: 3-pounders and light $4\frac{2}{5}$-inch howitzers had also been employed, and the British Artillery in Sicily were

provided with howitzers of the latter calibre, of the weight of 2½ cwt., on a low carriage or bed without wheels, adapted to be carried on mules; and of this calibre and construction two batteries were organized on the north coast of Spain, in 1836.*

In 1822, the French Artillery began a series of experiments on mountain guns, which ended in the final adoption, in 1828, of a 12-pounder howitzer of 6·22 calibres length of bore, and of the weight of 100 kils. (220 lbs. E.): the charge employed is ·27 kil. (9½ oz. E.): it ranges with 2° of elevation about 440 yards, and with 4° about 720. The extreme range extends to 1200 or 1300 yards. Its fire of common case is effective at 275 yards, but it will reach to 440 yards, and at this distance the balls pass through an inch deal. With spherical case the effect is good at 770 yards, and is still destructive at 1000. The penetration of the common shell in earth, at 440 yards, is 17½ inches; at 880 yards, 12 inches; and it furnishes on the average seventeen splinters.†

Spain adopted, in 1837, without any material change, the French system; the howitzer and carriage being the same, with some trifling variations in weight that will be seen below. The principal difference is, that while the French mountain howitzer is occasionally in draught, when the ground permits, by means of a pair of shafts that fit to the trail, the Spanish Artillery do not employ that means of transport at all.‡ They likewise have adopted a pack-saddle of their own, somewhat heavy and bulky, but a very good one; and we have it on the authority of the British Officers who were attached to their armies during the late civil war, that their mountain guns constantly accompanied the divisions to which they were attached, over all descriptions of ground, without causing delay or embarrassment of any kind, frequently making good, daily, marches of from 8 to 12 Spanish leagues without difficulty, with less distress to the cattle than to the horses of the cavalry, and, above all, without sore backs.§ Lieut.-Colonel De Salas, of the Spanish Artillery, in a little work, printed in 1844,‖ further supplies the fact, that in two years, ending in June, 1841, during a considerable portion of which the operations were most active, the loss of mules by death and being rendered unserviceable in five mountain batteries of 70 mules each, amounted, under all the disadvantages of a first essay, and with general inexperience, only to 61, being at the rate of 8⅗ per cent. per annum.

These results, and the experience of the French in Africa since 1830, afford proof

* These carriages permitted the howitzer to be elevated to 32°, and appear to have been designed for considerable elevations rather than for horizontal fire. They are too low to clear the ground in their front, and have other disadvantages.

† 'Aide-Mémoire de l'Artillerie,' 1844, pp. 411-437.

‡ This pair of shafts in the French Service weighs 28½ lbs., and must be carried when not used for draught. The English mountain 3-pounder gun is provided with a similar arrangement. It appears to be a good deal in use in Africa, where much of the country is level ('Mémorial de l'Artillerie,' 1843, v. 57): but the resource seems hardly to be necessary in other countries; for whenever mountain artillery descends into the plains, carriages will assuredly be found, and there can be no difficulty in procuring such as may carry easily the guns and carriages of a mountain battery, and the whole of the ammunition, if necessary. It seems needless, therefore, to be embarrassed with the means of draught in the battery itself; more especially since very few mules indeed will be found capable of the double function of carrying and drawing; and to this should be added the consideration that the footing of a mule customarily employed in draught cannot be depended on with a load in difficult ground. In the mountains, therefore, the draught mules will be idle, or can only carry a moderate load of forage or other supplies, and will not be available for the general service of the battery.

§ Of four marches in Aragon and the adjacent provinces, in 1838-9, amounting to 273 leagues in 33 days, each march performed without a halt, the shortest of which was 62 leagues in 7 days, and the longest 76 in 9 days, the day's march varying from 5 to 12 leagues, and the league fully equal to 3 English miles, the average distance daily was 8·28 leagues, or 24·84 English miles.

‖ 'Tactica de Artilleria de Montaña a Lomo,' 18mo, Madrid, 1844.

that must be deemed conclusive, both as to the efficiency in respect to movement, and the good service of the artillery in question.* And in France this consequence seems to have been arrived at—the total disuse of all ordnance between the mountain howitzer of 100 kilogrammes and the 8-pounder gun and 24-pounder howitzers of their field batteries, of 580 kilogrammes ($11\frac{2}{5}$ cwt.) †

In 1838 the French Artillery added to their materiel applicable to mountain service a small mortar of 15·13 centimetres calibre (24-pounder, or 6-inch), in weight 70 kilogrammes (154 ℔s.), which, with a charge ·14 kil. (4·9 oz. E.), ranges at 45° to about 660 yards, and at 15° to 385: the chamber will contain $7\frac{1}{2}$ oz. The British Artillery possesses mortars of $4\frac{2}{5}$ and $5\frac{1}{2}$ inches calibre (12 and 24 pounders), in weight 102 and 158 ℔s., and capable therefore of being carried on mules. They have frequently been employed with good effect, and require but small charges: the penetration of the shell, however, is but trifling, and a mortar of larger calibre, say 32-pounder, or even higher, which should still be within the limit of transport on the pack-saddle, appears to be desirable.

In considering the subject of mountain artillery it will be proper to notice a weapon that, from various causes, has not yet arrived in military estimation at a fixed or due value—the rocket. In circumstances that render the application of other means impossible it may be availed of, and, in many cases, with advantage. One of the qualities it possesses is that of a portability so complete as to render all positions accessible to it; and in some respects it has advantages, as, for example, in retreat, over the mountain howitzer. In the enfilade of a bridge, a ditch, a high road, or intrenchment, it is without doubt capable of proving a very effective weapon. It has also a power of penetration which is very considerable, and that, when it has attained nearly its maximum velocity, is at least double in earth that of round shot of the same weight with a full charge. Its maximum velocity being, however, considerably less than that of shot, it is not well suited to make impression on hard substances, though probably quite capable of effecting a breach in brick-work, at a proper distance. In long tubes and in calm weather, at 1000 yards, the 12-pounder rocket hits very nearly as well as a field howitzer, and penetrates in earth more than 12 feet.

To the ordinary service, however, of a country over which artillery on wheels cannot pass, the lighter rockets, 6 and 3 pounders, appear to be those best suited. Of the last, a mule carries easily fifty-six rounds, with all the necessary equipment; the weight of the load, exclusive of the saddle, being 276 ℔s.; and this calibre may be used on the march for the enfilade of hedges or other cover, from a flank in oblique fire, or to protect a retreat, carried in the hand, and halting only to fire. Of 6-pounder rockets, a mule may carry twenty-four rounds; but the sticks, from their length (7 feet) render the load inconvenient; and an improvement of construction is desirable. No fire, it is well known, is capable of a repetition so rapid as that of the rocket, and little is wanting to give this weapon a very important application in mountain warfare but the means of rendering it accurate in direction.

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* 'Mémorial de l'Artillerie, iv. 14, and v. 8.

† The 4-pounder field gun was finally suppressed in 1841.—Mém. de l'Art. v. 42.

The Establishment of the Mountain Batteries of Spain, as determined by Royal Order, February 18, 1844, is as follows.

12-pounder howitzers.	Rounds per gun.	Total Number of Rounds.	Officers.	Non-commissioned Officers, Trumpeters, Artificers, and Gunners.	Riding-horses for Non-commissioned Officers and Farriers.	Pack Mules.	
6	80	480	5	115	6	55	The horses of the Officers are not included.

One-fourth of the ammunition is case-shot. One ammunition mule only marches with each howitzer when ready for action,—making, with those carrying the howitzers and carriages, 18 mules per battery, each mule being conducted by an artillery-man. Eight non-commissioned officers and men are attached to each howitzer for its service,—to load and unload it and the carriage, and to supply ammunition while in action. The rest of the mules are considered as reserve, and are in the charge of artillery-men, one man having the care of two mules. They act as muleteers.

The mules are distributed as follows:

	Mules.
6 subdivisions of 3 mules each, carrying the howitzer, the carriage, and 1 pair of ammunition boxes, containing 16 rounds per gun and 96 per battery	18
24 loads reserve ammunition, 384 rounds per battery	24
For stores, tools, and forage	7
Spare howitzer carriage	1
Spare mules (unsaddled)	2
For officers' baggage	3
Total	55*

The French Mountain Batteries, consisting also of six 12-pounder howitzers, carry 165 rounds per howitzer, of which 20 rounds are common case and a portion spherical case,—making 990 rounds per battery. Each battery has 100 mules; but in this number are included 15 for the transport of infantry ammunition (30,000 rounds), also 2 mules spare.† The establishment of non-commissioned officers and men is not stated. When first formed, the French Mountain Batteries of six howitzers carried 80 rounds per howitzer, and had attached 4 officers, 70 non-commissioned officers, artificers, and artillery-men, 11 riding and 74 pack mules, of which 9 were spare, the cattle being led and looked after by 47 conductors, who were either muleteers or soldiers of the Train. The total number of persons, therefore, exclusive of Officers, was 117. At this period the knapsacks of the men were carried on mules, 12 being assigned for the purpose; ‡ but the arrangement appears now to be discontinued.

The English Mountain Batteries on the north coast of Spain, from 1836 to 1840, consisted of from $4\frac{2}{5}$-inch or 12-pounder howitzers carrying 96 rounds per gun, and

* 'Tactica de Artilleria de Montaña,' Madrid, 1844.

† 'Aide-Mémoire,' 1844, p. 287. So small an allowance of spare mules in the French and Spanish Batteries can only serve when the means of replacing losses or casualties to cattle are immediately at hand.

‡ 'Aide-Mémoire Portatif,' 18mo, Strasbourg, 1831, p. 88.

there were attached 3 officers, with 60 non-commissioned officers and men, and 9 Spanish muleteers, 3 riding and 36 pack mules. The battery was divided into front and reserve, and there marched with the former, when ready for action, 2 ammunition mules per howitzer, carrying 48 rounds,—making, with those carrying the howitzers and their carriages, 14 mules and 192 rounds.

In the Establishments of the French and Spanish Batteries, it will be perceived that the total quantity of ammunition carried being as 2 to 1 nearly, the French battery averages more than 11½ rounds per mule, and the Spanish not quite 8¾ rounds, the package of ammunition being the same. The proportion of 80 rounds per howitzer in the Spanish Service is obviously too small. It ought at least to be 120 to 150 rounds per howitzer.

The comparative weights of the principal articles carried in the batteries of the three countries mentioned, reduced to English weights, are as follows:

	The Howitzer.	The Carriage.	A pair of Ammunition boxes packed.	The Pack-Saddle.	
				For Gun or Carriage.	For Ammunition.
	tbs.	tbs.	tbs.	tbs.	tbs.
France .	220	243	216	48	48
Spain .	208	265	219	86	70
England .	280	105	330	41	45

The English carriages, as has been stated, were without wheels. Exclusive therefore of side-arms, shafts, &c., and without forage, the greatest load of the French battery, saddle included, does not exceed 291 tbs.; of the Spanish, 351; and of the English, 375 tbs. But the mule of the French and Spanish batteries carries only 16 rounds, and the English 24, of which half are spherical case,—a load which certainly is excessive, and should be reduced, say to 20, or, perhaps, to 18 rounds. The weight of the English howitzer is also greater than it ought to be, by 30 or 40 tbs.; and it is too short as well as too heavy. An advantage of some importance was, however, afforded to the mule which carried it, by placing the howitzer across the back, in a saddle constructed for the purpose, instead of in the direction of the animal's length. By this means the centre of gravity was lowered several inches, and greater facility was afforded likewise for unloading and loading the mule in going into or out of action. Three men, with some little practice, were able readily to place the howitzer in the saddle or to unload it; though the weight, at the height of the eyes, of a man of good stature, was upwards of 90 tbs. to each. The carriages being without wheels, two of them were carried easily by one mule, together with a small assortment of intrenching tools,—the whole load, saddle included, being 303 tbs.

The construction and dimensions of the French and Spanish mountain batteries differ but little from each other, excepting in the pack-saddle,—that of Spain deserving the preference, though it would seem possible in this, for the howitzer, to improve the framing of the tree, and to reduce the weight. It is the 'Bât à la Catalane' of the French.

The height of the French wheel, in English measure, is 37·6 inches, its weight 51·8 tbs., and the span, from out to out, 31·3 inches. The height of the Spanish wheel is 37·1 inches, and its weight 59·3 tbs. English.

The recoil of the mountain howitzer is violent, and requires that both wheels should be dragged: this is effected by means of a rope passed from wheel to wheel,

the ends being brought together above the block of the trail. Unrestrained, the recoil would reach to 36 feet.*

The drawings annexed of the Spanish mountain howitzer and its equipment are from the 'Tactica' of De Salas, already quoted, and will afford an idea of its character in both Services. (See Plates of 'Mountain Artillery.')

The saddle for the howitzer is fitted for either howitzer or carriage, and an iron pin (*pinzote*) is attached to the framing of the tree on each side, upon which, when on the march, the wheels may be carried separately from the body of the carriage, and the centre of gravity of the load much lowered. When not wanted, these pins fold sideways upon the saddle.

The French batteries carry with them a portable forge, for which one mule is allowed, and six men for the conveyance of other tools, materials, and stores. The forge is the same as that attached to regiments of cavalry, and its total weight, with tools complete, and 24 lbs. of charcoal in a leathern sack, is 188 lbs. English.† In the Spanish batteries the forge is dispensed with, and three mules appropriated to spare shoes, materials, and tools.

Without doubt the mule is the best animal of burden possible for the use of artillery in a mountainous country: hardy and powerful, yet capable of subsisting on little and coarse food, he is liable to few disorders, sustains easily great changes of temperature, and, above all, is possessed of an instinct or judgment in the choice of his footing, when heavily loaded and in difficult ground, superior to that of all other animals, and by that means is able to pass safely where none else could do so. And in pace and in endurance he is equal to the utmost effort that can be made by any infantry whatever. In case of necessity, however, the horse of a mountainous country, (usually compact, small-boned, and of moderate size,) where accustomed to carry burdens, may to a certain extent supply the place of the mule, but not to advantage in comparison, or to the same quantity of load.‡

In Asia and Africa, the camel is often employed to carry guns of light calibre, and the power of this animal as to burden is considerably above that of the mule. But his pace is slow; he belongs especially to the plains and to the desert, and is totally unsuited to the mountains and to slippery ground.§

Among the means of transporting artillery in mountainous countries,—the former resource of infirm travellers,—the litter, carried between two horses or mules, which is still in use in some countries, has been proposed; but it is not properly a mountain equipment, and can only be made use of where the ground is gradual in ascent or descent, the turnings easy, and the distance not considerable. The extent of the load, at the utmost, with two very good mules, is about 450 lbs.; and in a descent that is at all precipitous, the front mule is very liable to fall, and to be severely injured.

In the French Service the first reserve of infantry ammunition is attached to their mountain batteries, as it is to their field batteries in the plains; but in an English army this arrangement is not likely to be followed. The proportion attached to the French mountain batteries is 30,000 rounds, carried by fifteen mules, of which five march with the front of the battery, and ten with the reserve. In the British

* 'Aide-Mémoire de l'Artillerie,' 1844, p. 411. † Ibid. p. 236.

‡ In Cornwall, Devonshire, and Wales, and in many of the mountainous parts of England, where the paths are steep and few roads exist, pack-horses are still employed; and in certain of the mining districts mules also are used for the conveyance of ores.

§ The Turkish army, in 1840-1841, carried 12-pounder field howitzers of the weight of about 5 cwt. on camels, from the coast to Jerusalem; but, though the ground was not of a difficult character for mules, the camels suffered severely, and many were destroyed.

Service the mules of the first reserve of ammunition will probably be attached to the brigades of infantry, as formerly, and will march in their charge.

Little has been written on the subject of Mountain Artillery in its present form that may serve as a guide in service, beyond what is contained in the Aides-Mémoires, and the authorities quoted; and experience is yet wanting to indicate with precision the rules of tactique according to which it should be employed. Decker* makes some important observations on the service of artillery in a mountainous country, but enters only briefly into the question of continued operations. Jamini, in the article 'De la Stratégie dans les Montagnes,' † presents the general conditions of offensive and defensive war in relation to the principal mountainous countries of Europe, but chiefly as to the operations of passage, and without reference to the use of artillery; nor does he in the short but important article 'De l'Emploi de l'Artillerie,' ‡ in the conclusion of his work, make any observation on its service in the mountains. In a word, the tactique of mountain artillery, necessarily dependent on that of the infantry, has yet to be created; and since this last must vary with the nature of the country (for all mountains are not alike), with its resources, with the character of the inhabitants and their relation to the contending armies, as well as with that of the troops employed, it would seem to follow, that in respect to mountain warfare, general principles only can be asserted,—that no system can be prescribed; and, in the words of Jamini, that 'c'est dans l'étude des faits que l'an peut reconnaitre *toute la vanité de théories de detail*, et s'assurer q'une volonté forte et héroïque peut, dans la guerre des montagnes principalement, plus que tous les préceptes du monde.' §

But in whatever manner operations may be conducted, certain general principles, results of experience, and precautions, will be useful; and the following precepts have been thrown together, not in the pretension of being complete, but that they may serve to remind an Officer in command of a mountain battery of some of the points to which his attention should be directed.

Examine by means of a mounted Officer, or non-commissioned officer, the paths in advance in the line of march and around, as far as practicable, and procure information from the inhabitants whose fidelity can be relied on; but in a difficult country trust to no one, either as to information or as a guide, that is not himself a muleteer or an accustomed traveller. The fatigue of cattle depends mainly on the choice of the path.

Avoid defiles and narrow passages as much as possible: in many countries the best paths are frequently along the ridge. One kind which occurs in a forest country it is necessary to be guarded against—it is that used by charcoal-burners, which is usually without an outlet. Employ tools and labour to improve a bad passage: this is better than to incur the risk of laming cattle.

Wherever practicable and proper to do so, take a different line of march from the infantry, in order to allow the cattle to move at their natural pace, and avoid the embarrassment of frequent halts.

In difficult ground, do not permit the cattle to be hurried, but allow the mules to pick their own way freely, and at their own pace. It is best not to attempt to lead them, taking care only that they do not crowd upon each other. In forests that are closely timbered, it will be necessary, perhaps, to lead, in order to prevent the derangement of the load by striking the trees, or against each other.

In very difficult and precipitous ground, it will sometimes be advisable to transport

* 'Tracté Élémentarie d'Artillerie,' Book ii. art. 13, p. 410. Paris, 1825.

† 'Précis de l'Art de la Guerre,' art. 29, p. 330. Paris, 1837.

‡ Ibid. art. 46, p. 598.

§ Jamini, 'Précis de l'Art de la Guerre,' p. 342.

the howitzers and their equipment wholly by men ; and if proper arrangements are made, this is by no means a difficult matter, and may save much time; it being possible to convey by hand, either in ascent or descent, the materiel of the batteries over ground that no mule can pass at all,—the cattle in such case making a détour.

The best positions for mountain artillery are those from which all around can be seen, but have only a moderate command, the fire becoming inaccurate when the angle of depression is considerable, and the projectile does not gravitate upon the charge. In many cases, the incurvated track of the shell and its moderate velocity, which does not usually permit it to lodge, will be found to lend itself favorably to the character of the ground, particularly when the circumstances of the enemy's position can be observed from a flank.

Take care, on coming into a position, that it has both an outlet and an entrance; and if necessary, make one: time may otherwise be lost in moving in advance; and in case of retiring, the batteries may occasion delay to the troops, and be exposed to impediments.

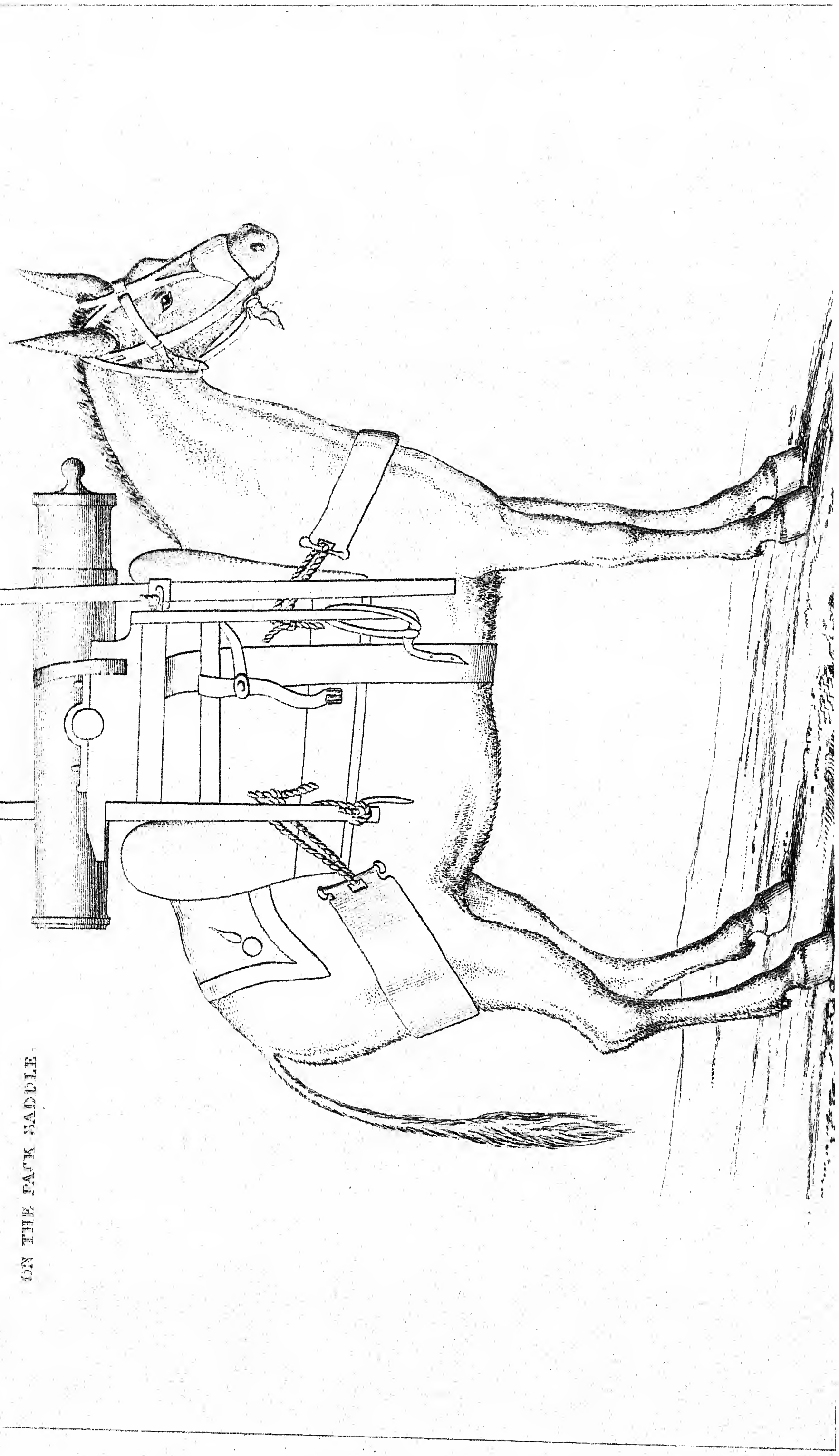
Examine well the confluence of valleys and all the paths which converge or issue from them; and take care, as far as possible, to command them. Obtain the enfilade of a communication, of a position, of cover, or of a probable deployment, whenever possible, and if not, an oblique fire. If the enemy be intrenched, and has the hill above him, direct on it shells with long fuzes, and let them roll into the trenches. This will oblige him to seek security by means of a counter-ditch, and the existence of this precaution will shew the ground he intends to dispute. If houses are occupied by the enemy, the walls will resist the fire of the mountain howitzer, unless formed of slight materials; but roofs in general are easily penetrated. Occasionally high angles of elevation may be useful, and the shells may be partly filled with lead to give them penetration. When this kind of fire is employed, it will be proper to maintain the elevation constant, and to vary the quantity of powder. Charges may be weighed and assorted beforehand, so as to admit of being adjusted by small additions, without delay.

As a general rule, economize ammunition to the utmost, and avoid all desultory firing without an object; but be prepared to open and concentrate your fire, and if possible, that of several batteries, at a decisive moment, not by assembling them on the same ground, but by the convergence of their fire. Bring as few mules under fire as possible, relieving them as their ammunition is expended.

As in all other cases, the correct estimation of distance, and the precision of fire *on opening*, is of the utmost importance. Place on each flank an intelligent non-commissioned officer to watch and report the fuzes, and the effect of your fire. The moral effect of the fire of artillery is best produced by occasional pauses, when its effect is not important, by ascertaining the point on which it can be directed to most advantage, and then, having duly employed the interval in preparation, throwing in suddenly upon that point a well-directed and concentrated fire.

Discover, if possible, the enemy's object and method of attack, if he be the assailant, and throw in on the head of his columns a mass of fire, attending more particularly to the defiles through which he may have to pass. In a fixed position, avail yourself of every means of rendering it secure. If the attack be on your side, take care to choose ground that will enable you to support it to advantage, to concentrate your fire upon the points to be assailed, and to follow up success.

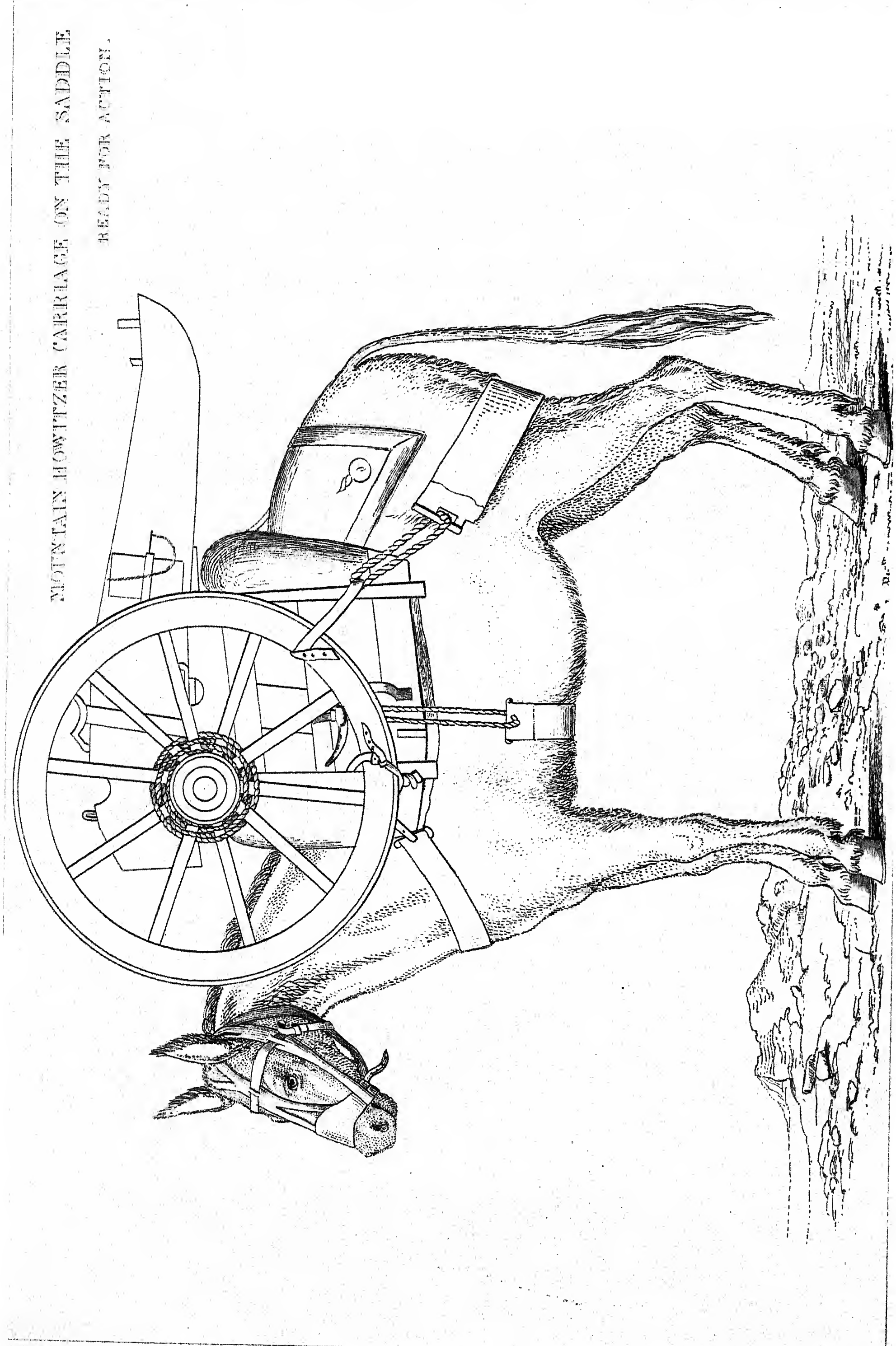
Great attention must be paid at all times to the equilibrium of the loads, but especially after ammunition has been expended.



SPANISH MOUNTAIN HOWITZER
ON THE PACK SADDLE

J. W. Lowry fc.

Published by John Weale, 59, High Holborn.

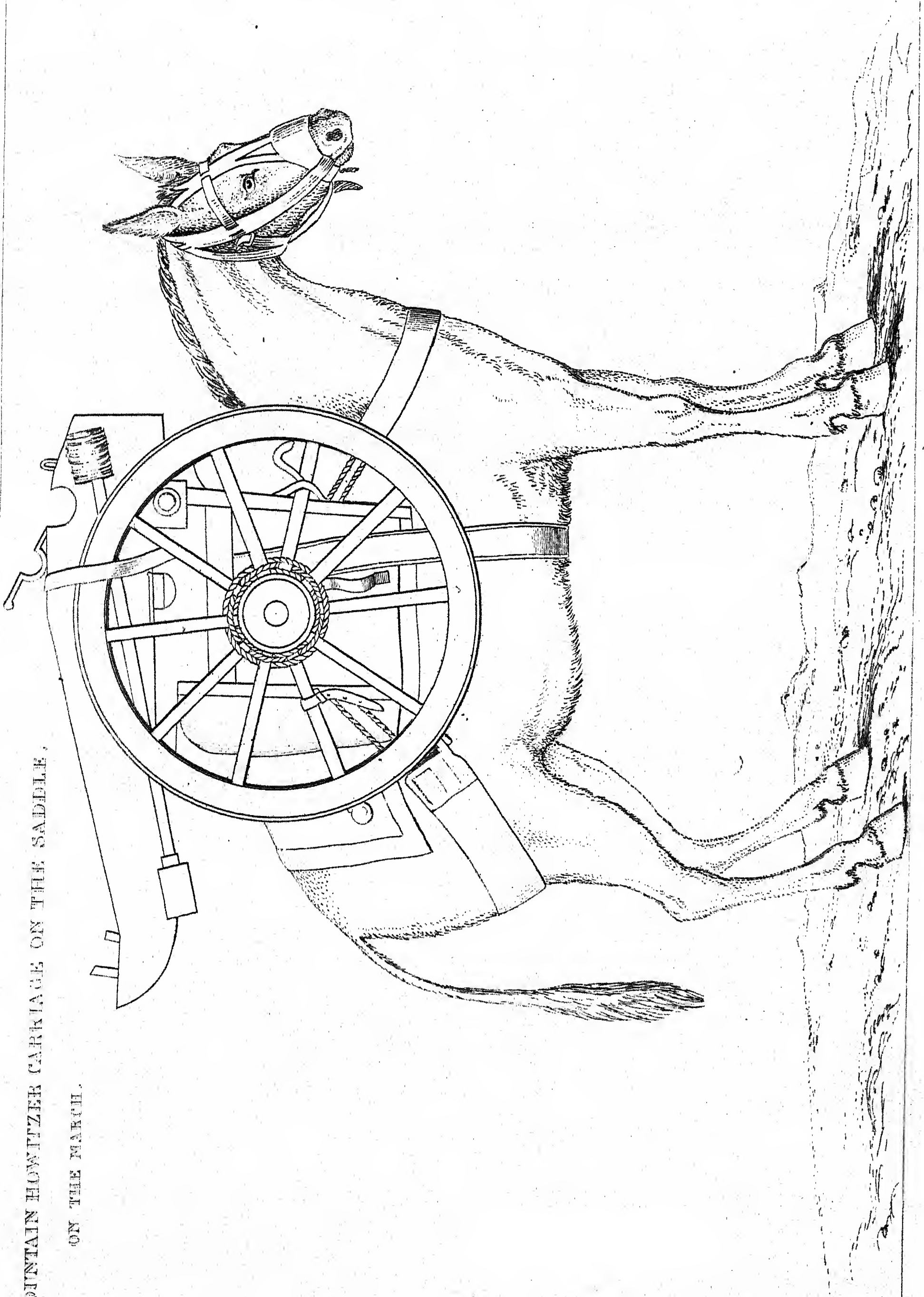


MOUNTAIN HOWITZER CARRIAGE ON THE SADDLE

READY FOR ACTION.

J. W. Lowry fc.

Published by John Weale, 59 High Holborn 1849.

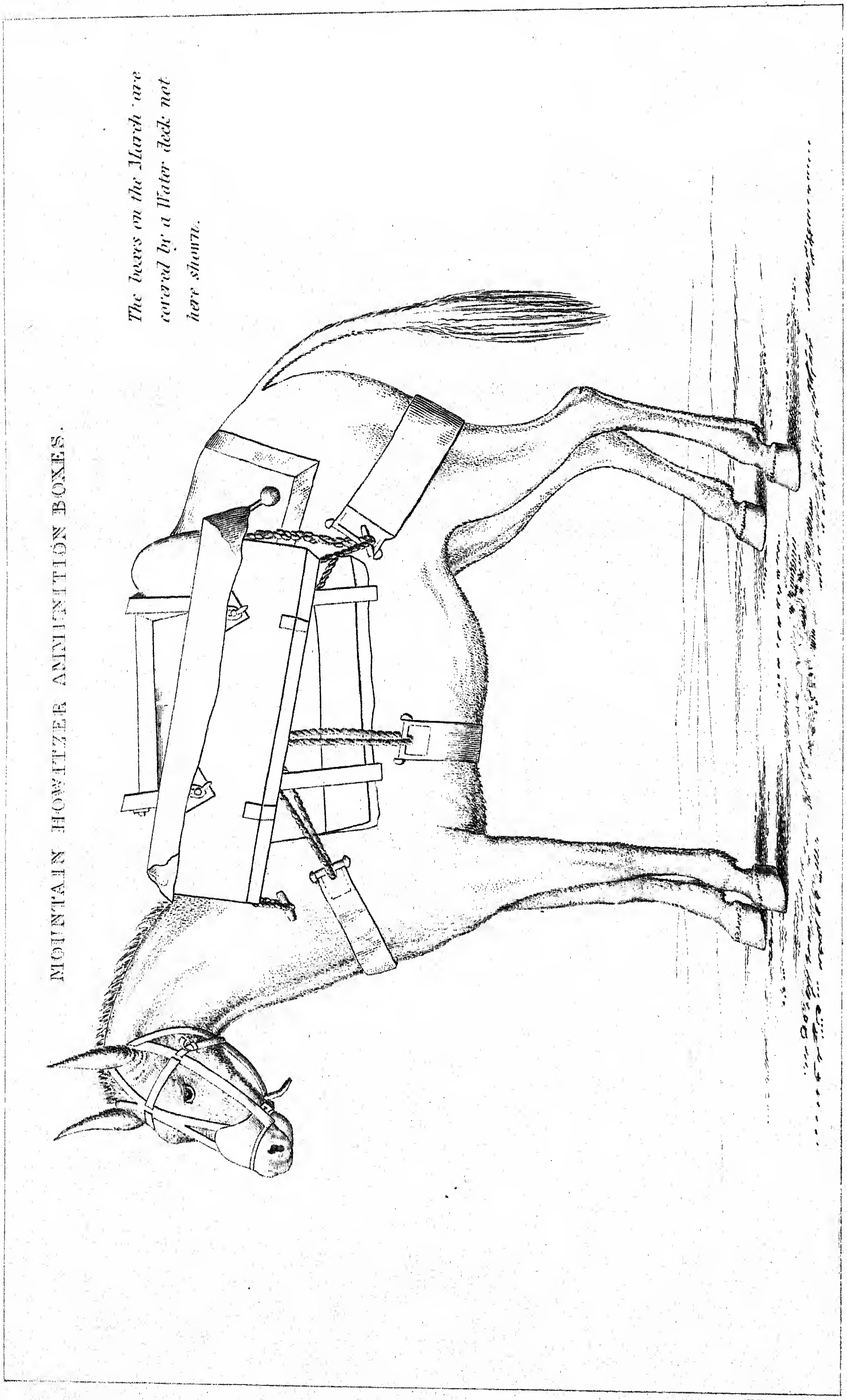


MOUNTAIN HOWITZER CARRIAGE ON THE SADDLE.

ON THE MARCH.

J. W. Lowry fc.

Published by John Weale 59 High Holborn 1849.

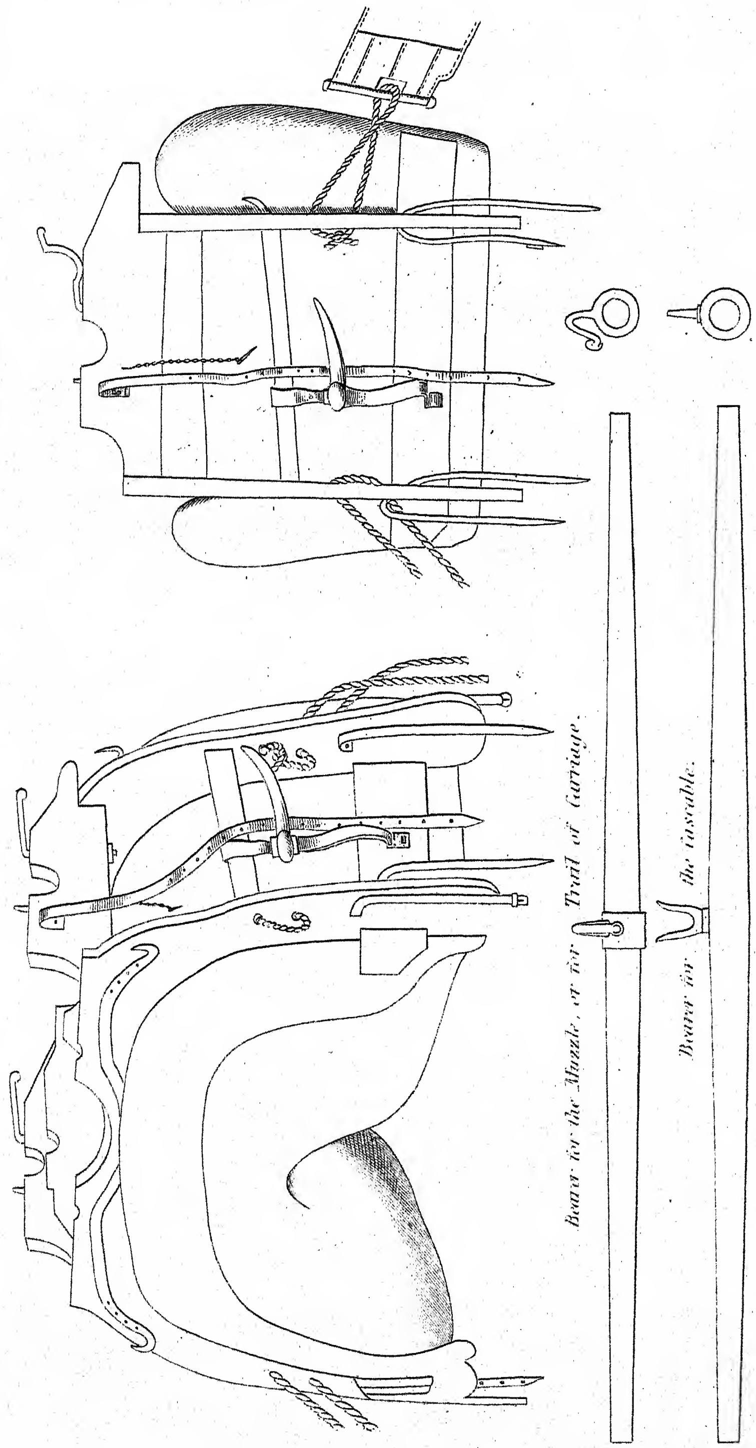


MOUNTAIN HOWITZER AMMUNITION BOXES.

J. W. Lowry sc.

Published by John Weale, 59, High Holborn, 1849.

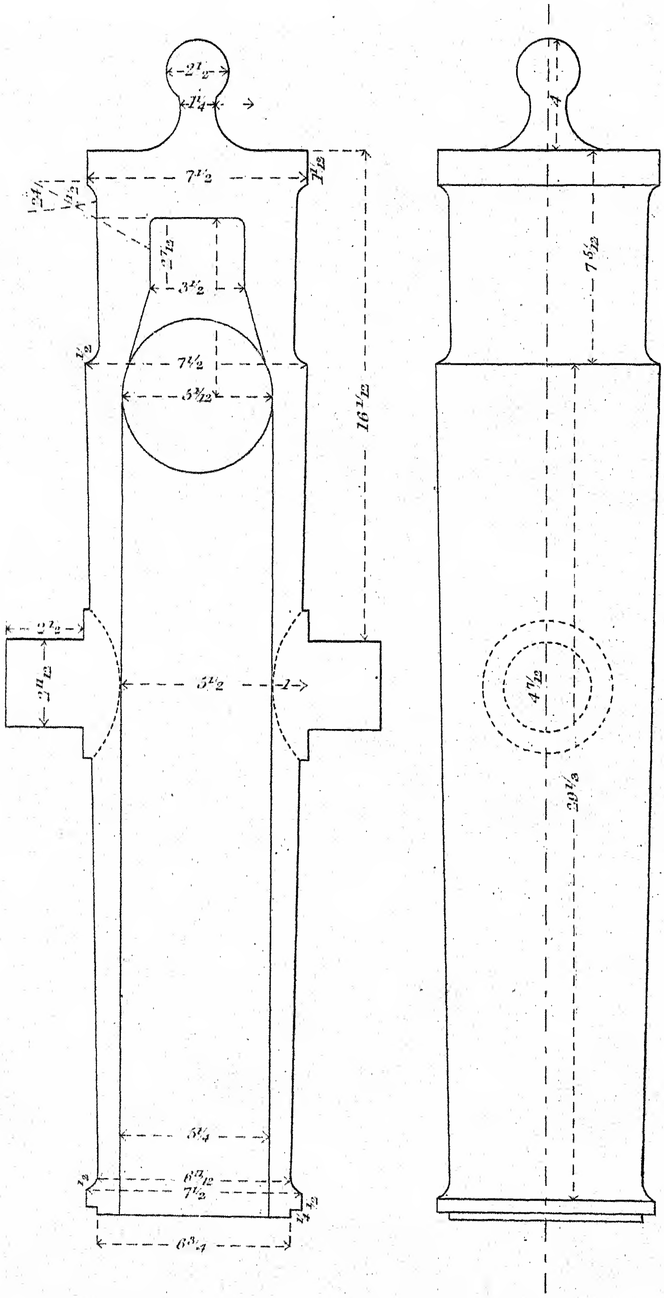
PACK SADDLE FOR MOUNTAIN HOWITZER ON CARRIAGE.



J.W. Lowry fc.

Published by John Weale, 59, High Holborn 1849.

SPANISH 12 P.R MOUNTAIN HOWITZER.



The Dimensions in Castilian Inches. The Foot equal to 11.128 Inches English.

J. W. Lowry fc.

Published by John Weale 59 High Holborn.

Whenever a halt occurs of sufficient continuance, and circumstances permit it, let the cattle be unloaded, taking care, while halted, and whether loaded or unloaded, that they do not roll.

Carry at the least half a day's corn with each mule, but do not feed on the march, unless the halt is considerable. Do not usually carry more than one day or a day and a half's corn on the loaded mules; it is better, when necessary to carry forage, to have mules assigned for the purpose.

No baggage of any kind is at any time to be allowed to be placed on the mules of a mountain battery, excepting on those appropriated to the purpose, on pain of being cut off and abandoned. The men should carry their knapsacks, reduced to what is absolutely necessary, and their great coats. In the French Service, the knapsacks were at first carried on mules, but this practice is discontinued.

Whenever the battery arrives on a plain where carriages of any kind are to be obtained, procure them, and the cattle necessary to convey the loads, until the ground again changes.

Never unsaddle, when the march is over, in less than an hour and a half to two hours from the time of halting.

In some countries it is customary to place ammunition carried by mules in the church, where lights and fire are easily interdicted. This is usually a convenient arrangement, access in general being easy on all sides; but care must be taken to secure the entrance, and that there be no impediment to turning out quickly when required. If infantry ammunition is also deposited in the church, a different entrance should be assigned to it. Marks to distinguish the cattle and their subdivisions are easily made by scissors in the hair of the off-side of the neck or rump, in numerals 4 to 5 inches high, and other marks may also be made in the hair of the tail by straight cuts across, a few inches below the root, to denote the battery to which the mules belong.

Allow no harshness to be employed towards the cattle without necessity, which can very rarely occur. The mule is far more obedient to the voice than to any means of punishment whatever, and though resentful, is much more sensible of good treatment and of attachment than generally supposed.

Great attention must be paid to shoeing, and to the condition of the feet: every mule must carry a fore and hind shoe fitted, and two sets of nails to each, and the farrier a full set. The Spanish and Turkish methods of shoeing are the best. In some countries, mules work without being shod behind; and in ground where the rock is hard and smooth, this is of great importance, through the security it affords.

The utmost care is also to be given to the pack-saddles, which are to be fitted to every mule, and never changed but from necessity. If, notwithstanding all the care that can be taken, a gall should occur, the saddle must be eased at that point by thinning the stuffing, to remove the pressure.

This article cannot be more properly concluded than by stating, that whatever may be the efficiency a mountain artillery perfectly well organized may arrive at, the moment that the army quits the mountains to descend into the plain, the proper field artillery should be resumed; for of this arm it is assuredly true, that *the heaviest that can perform the movements required to accompany and support the troops is that which ought to be employed.*

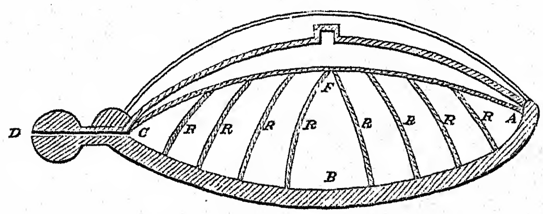
J. N. C.

MOUNTAIN BAROMETER.—Since the publication of the first volume of this work, in which the article BAROMETER was given at page 114, a new instrument has been brought into use, which is likely to facilitate the determination of heights above the level of the sea, called the *Aneroid Barometer*, of which the following description is given, previous to an explanation of some experiments which have been made to ascertain its value in measuring the heights of mountains not much exceeding 2000 feet.

ANEROID BAROMETER.*

"M. Contè, in his balloon ascents during the war in Egypt, found the ordinary barometer subject to so much oscillation that it was useless. He was the inventor of the Vacuum-Vase, and the following is a copy of his instrument, and the description he gives of it, extracted from the 'Bulletin des Sciences, Floreal,' an 6, page 106.

Fig. 1.



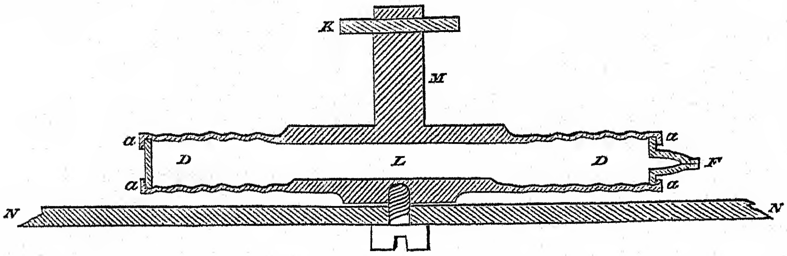
"'M. Contè, Professor of the Aërostatical School at Meudon, near Paris, and now in Egypt, has occupied his attention for some time past in adapting a barometer which, although of simple contrivance, should be more sensitive than those already in use. We now proceed to explain the first of his discoveries. It is very like a pocket watch. (See fig. 1.) A B C is a bowl made of strong iron or copper, upon which is a cover, C F A, of a very thin sheet steel, and the edges of which must be fitted with great exactness. The springs, R R, keep the cover at its elevation; and while they regulate its action, the air is pumped out of the bowl, A F C B, through the opening at D. This opening shuts itself so as to be air-tight, and then the whole weight of the atmosphere forces down the flexible bowl, C F A. Now, as the resistance of the springs remains constantly the same, this cover-plate rises or falls as the atmospheric pressure varies; and these variations are shewn by means of a hand, securely fastened, which passes backwards and forwards upon a divided plate.' The discoverer, however, acknowledges that he was compelled to reject this instrument, on account of the prejudicial influence which the change of temperature had upon it.

"From the above diagram, there may be adduced many strong reasons, besides that which M. Contè has stated, to shew why he was not successful. The principal one would readily suggest itself to any person of mechanical information. The figure he chose as the object of atmospheric compression is, perhaps, of all forms, the worst adapted for that purpose; viz. an *arch*. That he has recorded the principle cannot be disputed; but when we consider what has been stated relative to the form of his vacuum-vase, to say nothing of its inadequately small dimensions, we must be permitted to question if he ever obtained any practical result. The extreme ingenuity of M. Vidi, the inventor of the instrument about to be described, appears, then, to be in no way disparaged by the claims to the invention of the principle, which have been set up for M. Contè by his friends.

* From a 'Treatise on the Aneroid,' by Edward J. Dent, F.R.A.S., &c. &c. &c.

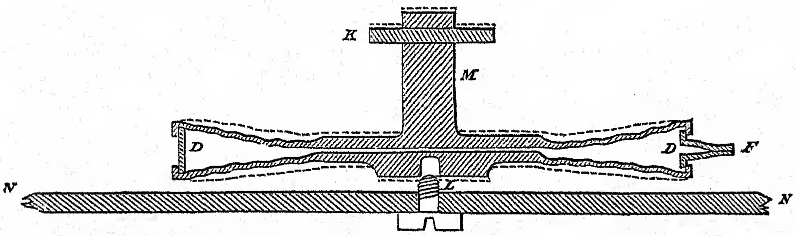
"A diagram and explanation of M. Conté's vacuum-vase having been given above, it will be proper to detach and exhibit on paper that of M. Vidi, that the difference between the two may be shewn more clearly, and that the ingenious means adopted by M. Vidi to correct for varying temperature may be the better appreciated.

Fig. 2.



"In fig. 2 the vacuum-vase is represented in the shape which it presents before it is exhausted by the air-pump: *a a a a* shew the turning or lapping over of the thin corrugated diaphragms where they are soldered to the rim; D D is the vacuum-vase; M is the socket, which, being pulled by the pin K, places the vase in a state of tension, whereby it offers resistance to the pressure of the external atmosphere.

Fig. 3.



"Fig. 3 shews the vacuum-vase in a compressed state, after the air has been exhausted by the air-pump, through the tube F. The dotted lines, running nearly even with the corrugated surface, are intended to shew the position which that surface will assume after the introduction of the gas, which effects a compensation for the results of varying temperature.

"From the circumstance of a gas being (perhaps for the first time) introduced into an instrument with a view to effect a correction for variable temperatures, and from its being an invisible agent, a short explanation may be required in verification of its being adequate to produce the results asserted. Such an explanation will serve to impress on the attention of those who study mechanical science, how important it becomes to take into their consideration, not only the expansion of metals upon an increase of temperature, but also the loss of elastic force, to which, in a state of tension, they become subject. The student is familiar with tables indicating the expansion of metals; but, even at the present time, no table has been calculated in order to shew the loss sustained by elastic bodies when in a state of tension: perhaps no instrument, although made for the express purpose, could exhibit an experiment more satisfactory for the proof of this point than the aneroid. We are enabled to use it as a pyrometer by applying the heat of a lighted taper to the spring S, fig. 5,

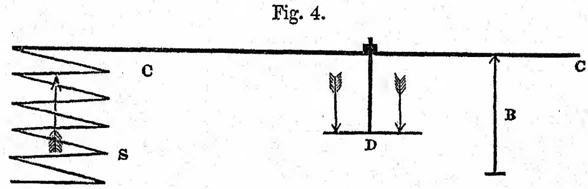
without communicating that heat to the vacuum-vase. A table of direct expansion would cause us to conclude, that as the spring S would, on being heated, become longer, it would raise the lever C higher; but the experiment above adverted to produces a contrary result, (for the spring S, losing its elastic power through heat, is forced down by the atmospheric pressure on the vacuum-vase,) and proves that the loss of elastic force is greater than that of direct expansion. The hand of the aneroid indicates this, by moving towards the right, or 'set fair.'

"We might further suppose that an increase of heat, expanding the metal of which the vacuum-vase was made, would proportionately increase its capacity; whereas the contrary is actually the case;—a conclusion which is proved by heating the vacuum-vase alone. It must be admitted that the metal diaphragms have become both larger and weaker by an increase of temperature, whence the capacity of the vacuum-vase would be rendered greater; but it must be also remembered that the atmospheric pressure on the surfaces, amounting to a force of 44 lbs., brings the upper and lower diaphragms, thus weakened by heat, closer together, so that the cavity of the vacuum-vase has, in fact, become smaller.

"This brings us to the subject of compensation accomplished by gas. On the capacity of the vacuum-vase being diminished by heat, as has been just shewn, the gas contained within it is, by the same cause, expanded; and, resisting the compressing force of the atmospheric weight upon the diaphragms, keeps them separated at a due distance, and effects the compensation.

"The vacuum-vase is brought into a state of tension by separating the diaphragms, after exhaustion, and placing the pin K on the lever C, as shewn in fig. 5. The lever C is then to be placed on its fulcrums, B B, and the other end of the lever C to rest on the top of the spiral spring S. The action of the atmosphere on the vacuum-vase, and the connection of the latter with the spring S, require to be clearly understood, in order to a perfect acquaintance with the principle of the aneroid. To illustrate this still further, it appears necessary to give a diagram explanatory of the theorem.

Fig. 4.



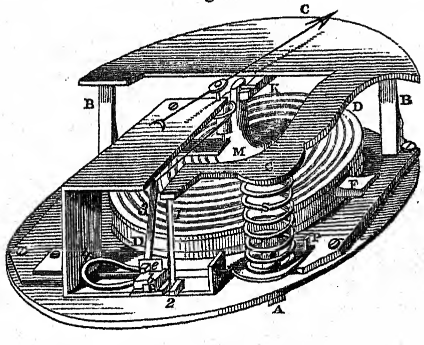
"D represents the vacuum-vase. The arrows indicate the downward pressure of the atmosphere, which alone keeps the lever C on its fulcrum B, as well as on the *top* of the spring S. This spring is compressed by the atmospheric force on the vase; whence it will be seen, that if the vacuum were destroyed in the vase, the lever C would instantly fall off its fulcrum, as well as off the top of the spring S. The lever C, it may be remarked, is of the second order.

"Let us suppose an increase of atmospheric pressure on the vacuum-vase to take place; the fulcrum B would remain, of course, firm and unaffected. The surface of the vase D would be forced downwards, and the spring S, at the same instant, still more so, as must be apparent from considering the increased distance of the lever, which in the aneroid is as six to one.

"A few words may be required for the further illustration of this subject. We know that the atmospheric pressure is about 15 lbs. to the square inch. Now the vacuum-vase being 2½ inches in diameter, this surface gives for its product a

pressure of about 73 lbs. on the vase; though, from many causes, this amount of atmospheric pressure is considerably reduced. In order to ascertain the actual weight produced by the atmosphere upon the surface of the vacuum-vase, recourse was had to an experiment affording positive demonstration. The hook of a steelyard, or spring weighing-machine, was attached to the upper part of the vase by the pin K (fig. 5), and, on being pulled up to the point parallel to the top of the vase, shewed the weight of 44 lbs.; which is, therefore, proved to be the force by which the lever C is kept on its fulcrums B B, and on the top of the spring S.

Fig. 5.



"It is hoped that the principle of the aneroid has, from the foregoing explanations, been made sufficiently intelligible; and, if so, it will be an easy task to describe the remainder of the mechanism. We will now refer to the perspective drawing of the interior of the machine: D D, vacuum-vase; C C, lever, to the end of which is attached a vertical *rod* (1), which merely serves to connect the lever C C with the levers (2 and 3). These levers are connected by a bow-piece (4). The two square-headed screws at *e b* admit, by screwing or unscrewing them, such an alteration of the distance of leverage as to allow the hand of the aneroid to move over a space corresponding with the scale of a standard mercurial barometer. To the end of the lever (3) is attached a light rod, terminating with a piece of fine watch-chain, which is attached to a small roller. On the axis of this roller the hand of the aneroid is firmly fixed, and kept in its position by means of a flat spiral spring, the outer coil of which is seen attached to the axis. This flat spiral spring, which is always in a state of tension, maintains a pressure against the force of the levers, and keeps the hand of the aneroid in obedience to the indications of the vacuum-vase. Were it not for this spring, the hand *b*, fig. 6, would remain stationary at the point to which it had been propelled.

"*To set the hand of the aneroid to correspond with any other barometer.*—A, the head of the screw, figs. 5 and 6, to be considered as at the back of the case. This screw A, when screwed or unscrewed, alters the position of the hand, *and is not to be touched for any other purpose.* It acts in a piece of brass, seen at P in fig. 5, which is prevented from turning round the spring S by means of a pin inserted in the plate. When the screw A is moved, it raises or depresses the lever C C, whence motion is communicated to the hand.

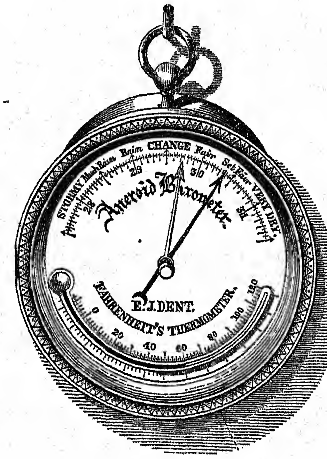
"*To register the variations of the aneroid.*—A nut, as seen at O, fig. 6, projects through the centre of the glass, to enable the observer to move the gilt index W beneath it. By this gilt index the registration of the hand *b* is effected. The two hands having been placed exactly parallel, by turning this nut, and bringing the gilt index W immediately over the hand *b*, should the latter have subsequently deviated from W, either to the right or the left, the difference will be the result of increased or diminished atmospheric pressure.

MEASUREMENT OF HEIGHTS.

"A less common, but very easy and interesting use of barometrical instruments, is

to ascertain the variety of altitudes from the surface of the sea; to which purpose the aneroid is, from its portability, exclusively adapted. By the application of this elegant little instrument, an opportunity is afforded the traveller of learning the level of the railway along which he is passing, even at the utmost speed of the engine. It must be allowed, at least, that no *mercurial* barometer can accomplish *this* purpose. The tourist may by the same means observe the delicate movement of the hand of the aneroid approaching from the word 'fair' to 'change,' as he ascends. So much will this instrument increase the agreeableness of travelling, and supply its possessor with subjects of entertainment and materials for his journal, that it may fairly be anticipated as likely to become the almost indispensable companion of every one who travels either for knowledge or recreation.

Fig. 6.



"An amusing experiment for showing the delicate sensibility of the aneroid, and its power of measuring small heights, may be tried in an ordinary dwelling-house. Any one, on ascending from the basement to the attic, will perceive the gradual approach of the index from 'fair' to 'change,' &c., as noticed above; and its return to its original position, whenever he descends from the attic to the basement. The tenth of an inch is subdivided on the face of the aneroid into four parts; and, generally speaking, if the hand goes back one-tenth of an inch, we may fairly conclude that we have ascended from our starting-point about 85 feet; and, of course, *vice versâ*. Calculations may be made according to this proportion."

In the months of May and June, 1849, Major Robinson, R. E., undertook the task of verifying the use of the aneroid at Portsmouth, and the height of Portsdown Hill was accurately measured by a good spirit-level, and some experiments tried, which at first were not favorable to the aneroid; but on investigating the construction of the instruments, it was found that each should have its own register for indicating heights, from certain peculiarities in their mechanism.

Major Robinson, therefore, taking one sold by Messrs. Manuel, of Portsmouth, (No. 2775,) to the dome of St. Thomas's church, measuring exactly 100 feet, found that ·10 of an inch gave 95 feet, which was verified by going to the summit of a tower at the Point, measuring 75 feet in height.

In measuring Portsdown Hill with the same instrument, he found that 95 feet for every tenth of an inch gave the height 337·6 within two feet, as measured by the spirit-level.

It would seem, therefore, to be necessary, previous to measuring heights, to ascertain practically what the height of 100 feet will be registered by the hands of the aneroid; and as this check may be made as frequently as doubts arise by apparent discrepancies in comparing one aneroid with another, or comparing them with the mercurial barometer, it is conceived that this instrument may be found desirable from its portability, and the simple mode of finding any height provided the altitude does not exceed 2000 feet.

The means of reading the divisions more accurately, in the aneroid, must be

obtained before *very accurate* and small differences of height can be measured by them: perhaps, if some tracing-paper, with the divisions marked to correspond with the dial-plate, were fixed on the glass by a little gum, the position of the hand would be accurately ascertained; for at present, the eye being placed to the right or left, will cause a variation in the reading.

Major Robinson found that temperature had an effect upon the aneroid he used, amounting to 0·01 of an inch for every five degrees.

G. G. L.

MULE FOR BURDEN.*—The mule is the best beast of burden in a campaign. He is, perhaps, naturally obstinate and intractable, but he possesses many valuable qualities to compensate for these defects. He is strong, temperate, bears great heat, sure-footed, easily fed and got into good condition, but very delicate about the water he drinks. He does not stand fire so well as the horse, and is consequently not so well adapted for draught in Field Artillery; but for Mountain Artillery he is admirably suited.

The mule is seldom sick, but when so, it is frequently fatal: he usually commences work at three years old, though four is a better age, and he continues able to work till about twenty-five.

The produce of the male ass and the mare is preferred to that of the horse and the ass, being much larger and more powerful, but not, for his size, stronger. They may be easily distinguished by their resemblance to their sires: the former also brays, and the latter neighs.

The mule, in Military Service, carries a cargo of from 200 to 300 lbs., with which he can conveniently travel eight leagues (of three miles each) a day, at three to four miles per hour, which is as fast as any infantry can travel.

With light loads he can keep up with cavalry at a trot, from four to six miles per hour.

Mules may be divided into three classes:

	Can carry
1st class. From eight to twelve years old, a little more or less, ...	300 lbs.
2nd class. Twelve years and upwards, and from five to eight years old, .	250 ,,
3rd class. Young mules under five years old, and very old mules, . . .	200 ,,

In a campaign subject to forced marches, indifferent food, and bivouacking, from 200 to 225 lbs. are considered a sufficient load; because the muleteer, when out of sight, is very apt to ride on the mule.

In Spain, the mules are used for draught instead of horses, even in carriages: the female is preferred for this purpose, as being more tractable than the male, though not so strong.

Those bred in La Mancha, and those bought at the fairs of Padua in Galicia, and Zamora, and fed in the pastures of La Mancha, are preferred for this purpose.

The mule varies from thirteen to sixteen hands high, and sometimes even exceeds this height. The ordinary price is from £10 to £30, and even £60 is frequently given when broken in for the carriage. It is the custom to clip the mule for cargo over the back, breast, and thighs; that is, over each part touched by the pack-saddle, the breast-plate, and breeching, to prevent sore backs and galling.

The pack-saddle weighs about 60 lbs.: there are various modes of loading.

1st. A pair of panniers of grass, of a triangular or sugar-loaf form, with the peak

* By Colonel Alderson, R.E.

downwards, thrown over the pack-saddle, the two points being connected by a rope under the belly.

2ndly. By two bales, portmanteaus, canteens or ammunition boxes, containing 1000 rounds of ball-cartridge each, or other heavy substances of nearly equal weights, so as to balance each other. These are suspended on each side of the ridge of the back, as high as possible, by means of ropes passed round them. Such other light articles as are required to make up the load are placed on the back, between the two heavy articles preserving the balance.

A woollen cover, or tarpaulin, is then placed over all, and corded tight.

When the mule is strong, or the load light, the muleteer jumps upon the pommel of the leading mule, having one, two, or more fastened by their halters to the pack of the mule in front of them.

3rdly. By small panniers, or baskets of wicker-work, two or three on each side, connected together, and suspended by loops and toggles. This is the general mode of loading a sumpter mule; and if lightly loaded, he will carry your cook, who will be ready to select your billet and prepare your food.

4thly. By two large rectangular panniers, like a writing-case, or lady's reticule, and made of stiff portmanteau leather, with or without partitions in them. They are loaded in a moment, like those of the sumpter mule, with loops and toggles, by two persons, one on each side, lifting them at the same time: the mule is then ready to march.

In countries where you cannot be certain of obtaining a regular muleteer, as in Spain, &c., this last *is by far* the simplest and best plan; the panniers, however, should not be made too large, or they will carry their weight too low, which is their only fault, and become inconvenient in crossing fords.

The mules of Syria are much less than those of Spain, and incapable of carrying the same weight: there, however, nature has provided the camel.

R. A.

MUSKET.—The small arms for Her Majesty's Service are manufactured chiefly at the Government Establishment at Enfield, under the able direction of Mr. Lovell, the Superintendent of Small Arms; but occasionally arms are supplied by contract, and delivered in at the Tower, where they are examined and tested by competent Inspectors, according to the Regulations, the barrels having been previously proved in the rough; they must also bear the proof mark.

The arms so received must be in every respect conformable to pattern; and such as are found defective are rejected, and returned on the contractor's hands.

WEIGHT OF SMALL ARMS.

DESCRIPTION OF ARMS.			Length of Barrel.		Weight of Musket.		Diameter of bore.
			ft.	in.	lbs.	oz.	in.
Muskets, complete with bayonets & rammers,	Flint	Land, Regular	3	6	12	3	·750
	Percussion	Land, pattern 1842	3	3	11	2	
		Sea Service	2	6	10	2	

	ft.	in.
Length of bayonet	1	6
Total length of musket	6	$0\frac{1}{2}$

WEIGHT OF THE SEVERAL PARTS OF THE PERCUSSION LAND SERVICE MUSKET, PATTERN OF 1842.

	lbs.	oz.
Stock, with bolts, pins, and caps	2	12½
Barrel	5	1¼
Bayonet and rammer	1	4½
Swivels and screws	0	4
Brass-work	1	2¼
Lock	0	10
Total weight	11	2½

A. Stewart, *Ordnance Storekeeper.*

The new French percussion musket* weighs 4·682 kils., or 10·3 lbs. English, with the bayonet.

Thirty-four balls go to the kilogramme, which give about sixteen to the pound avoirdupois.

The musket is in length	4′ 9·87″
„ bayonet „	1 6·13
Total	6 4
Diameter of bore	·709 of an inch
Windage	·039 „

Note.—Erroneous ideas prevail as to the precise wants of the Service with regard to the musket, and its proper qualities and utility in the field, as well as much exaggeration as to the defects of the new percussion musket of 1842 for the Infantry of the Line.

It is stated that the new musket is still too heavy, and of imperfect construction. If so, what should it be? Some prefer the French pattern, weighing about 10½ lbs., carrying 16 balls to the lb. avoirdupois; and others would lessen the calibre and weight still more, reducing also the windage. As, however, the new Regulation has brought into use some hundreds of thousands of new muskets, and has been approved by the highest authorities, some considerations are necessary before a radical change can be effected, beyond range and a nice accuracy of fire.

1st, What are the essentials for a musket of the Infantry of the Line.

2ndly, The application of the musket to an infantry soldier.

It is evident that the most essential points are, strength, and facility of pouring into your enemy's ranks a powerful fire.

Troops on service do not halt to play at long bowls: a field of battle presents a series of movements for the purpose of out-flanking or closing-in upon your adversary, and, when within 200 yards, to deliver your fire with effect. Firing at 500 or 600 yards is a business of artillery; and therefore, when infantry fire is given at these long distances, or even 300 or 400 yards, it is a misapplication of the musket, a loss of time, and tends to make men unsteady: it is besides a waste of ammunition.

It may be desirable to arm all light troops with the rifle, including the light companies of regiments for especial uses; but it is very questionable whether any advantage would be gained in following the French system, or any other plan which would lessen the durability of the musket for the troops of the Line.

* From 'Instruction Théorique et Pratique sur le Tir à Feu, etablié par S. A. R. le Duc D'Orleans.

There is some misapprehension, likewise, with regard to the point-blank range of pieces. In the French Service, it is purely an arrangement of sights: in our Service, it is an imaginary line, parallel with the plane on which the piece is fired, and there is some difficulty in ascertaining it; whilst in the French Service it is a practicable and simple mode of regulating the elevation or depression.

Tolerable accuracy of fire may be obtained with the English percussion musket by careful instruction; and such defects as exist in the present method of teaching the soldier do not lessen the value of the arm.

(See the next Article, and also that on 'Point-blank.')

G. G. L.

MUSKETRY FIRE AND PRACTICE. * — The subject of this article is the use and effects of the musket as a military weapon, together with suggestions for the instruction of the soldier in firing and practice.

In order to make the fire of infantry soldiers as effectual as possible, and to train a body of men to become good shots, it is necessary that they should be convinced that the musket with which they are armed is one of well-ascertained quality, and that, if skilfully used, they may place the greatest confidence in it: in this view, they must be taught the theoretical rules by the aid of which it can be fired with the surest results, and this instruction must be conveyed in the method best adapted to their understanding; for untaught men are so much more disposed to endeavour to effect this by mere imitation of others, that great difficulty is experienced in teaching them on scientific principles.

The instructions on so important a branch of the soldier's training, hitherto given to the Army, have not been of so precise and detailed a description as to afford to regiments a uniform system of practice; and, to a certain extent, it does not receive the attention it deserves: otherwise the soldiers of the British Army ought to fire better than those of others, considering how much longer their service lasts. The same deficiency, however, existed in most armies of the Continent until recently; and even in the French Service a great want of system was experienced until the establishment of the École du Tir de Vincennes. The musket now used by the Army, with the percussion lock, is, for military purposes, a very efficient and serviceable arm: in the hands of expert and well practised soldiers, its fire may be considered most effectual up to 150 yards, and as far as 200 yards is to be relied upon: beyond this distance, though good shots may fire with effect, it becomes uncertain, and the imperfect points in the musket render its fire vague and unsatisfactory. As, however, the fire of infantry is not much required beyond 250 yards, the instruction and practice of soldiers may be conducted with a view to make them fire well up to that distance.

Description of the musket. The length of the barrel of the infantry musket is 3 feet 3 inches; its calibre ·75 in., and its weight with the bayonet near 11½ lbs.: it becomes frequently cumbersome to small men, and likely to have some effect on their firing, particularly after marching with it for any time. *Quality of the powder used for the cartridge.* The quality of the powder used since the introduction of the percussion musket has improved the firing, but the quantity in the cartridge is rather too great, causing the recoil to be excessive. In practice, better firing is attained by reducing the charge, particularly for short distances: half a drachm, the difference since the change from flint locks, is scarcely enough to allow for the priming: the French cartridge contains only 2·88 drs., being 1·62 drs. less than the English, which might be reduced with advantage from 4½ drs. to 3½ or 4 drs.

* By Captain Sorell, 81st Regiment.

Weight and size of the ball.

The weight of the bullet is 17·65 drs. and its diameter ·68 inch; the allowance for windage, ·07 in., is therefore considerable, and much exceeds that of the French musket, which is ·001^{mm}. or ·039 inch, and the German, which is ·047 inch: it must greatly affect the right flight of the ball; and to load, it requires to be well wrapped in paper. As the barrel becomes coated with the residue of the powder, the loading becomes more difficult; but with due regard to this, some closer approximation between the size of the ball and the bore might be made. For a military weapon, which must necessarily be rough and strong, the English infantry musket, with some improvements, would be as serviceable a one as in the present state of the construction of fire-arms can be expected. The construction of the lock of the musket used in the Austrian Army is worthy of consideration: the detonating powder is made up and attached to the cartridge, the lock being so made that it catches under a spring, so that by priming first, the act of detaching the detonator breaks the cartridge ready for loading: by this means the inconvenience of constantly biting cartridges, which in a long day's firing is very painful, is avoided.*

Ammunition allowed for practice.

The annual proportion of ammunition issued to the army for practice is as follows:

	Spring allowance, due 25th March.	Autumn allowance, due 29th September.
Infantry.	20 rounds ball cartridge, 40 rounds blank, for each musket.	10 rounds ball cartridge, 20 rounds blank, for each musket.
Light Infantry Regiments.	30 rounds ball cartridge, 40 rounds blank, for each musket.	20 rounds ball cartridge, 20 rounds blank, for each musket.
Rifle Corps.	60 rounds ball cartridge, 40 rounds blank, for each rifle.	30 rounds ball cartridge, 20 rounds blank, for each rifle.
Eleven percussion caps are issued with every ten blank cartridges, and fifty caps with every forty ball cartridges.		

This is considerably less than the French, which in the first year of the recruit's service is 80 rounds of ball cartridge, and 40 rounds each year after: much more practice is thus given to the recruits. The allowance made to Light Infantry Regiments might be given to all others, who are supposed to (and in most cases do) fire quite as well. It frequently occurs that a regiment or detachment is stationed at a quarter where ball practice cannot be carried on, either from there being no fit place or its too great distance: the practice ammunition is then not fired, or is expended in a hurried and useless manner. In such cases it would be more useful to permit the ammunition to remain un-drawn, until the corps removed to a more convenient place, and then to issue it to them in addition to what had since become due: this cannot now be done if the application for the Spring allowance be delayed to the 1st August, or for the Autumn allowance to the 1st December following. Many barrack stations are destitute of appropriate places for conducting ball practice, and many others, such as they now are, are very ill adapted to the purpose: where no place can be found, a shooting gallery might be arranged in any barrack square of sufficient size, by constructing square or arched screens, to prevent the danger of random shots. On every ground for ball practice, buts of earth should be thrown up: they are of the most essential service for placing the targets against, giving the

Ball practice grounds.

* It has been suggested that the percussion caps should be on the same side as the cartouch box.

eye some larger object to rest upon, and shewing how missing shots are directed: these may always be made by the troops themselves, under the authority of the Engineer Department.

Description of the target.

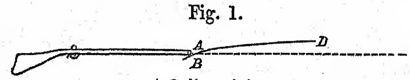
The targets for the use of the Army are issued by the Ordnance Department: they consist of an iron frame covered with white cotton: they are 6 feet long by 2 broad, and are divided by black lines into three equal compartments,—upper, centre, and lower; the centre division having a bull's-eye, 8 inches in diameter, in its centre, surrounded, at 2 inches distance, by a circle of an inch broad. No Officer who has superintended ball practice can have failed to observe the inferior quality of these targets. Placed in open space, without any object immediately behind them, they are of so flimsy a texture as scarcely to be sufficient to catch the eye; and when once much pierced by shot, they become so torn as to make it difficult to see where they have been hit: various kinds have been tried, and others suggested, but the present one, if the covering were of a more substantial quality, and laid with paper pasted upon it, would be serviceable enough. The French target, much of this kind, is 6 feet 6¾ inches by 22 inches, and its centre is similarly marked by a circle rather smaller in diameter: the other divisions are, however, placed more usefully, to indicate the degrees of elevation or depression required for the different distances in firing. For advanced and practised soldiers, they use a plain target, having no other mark but the circle; and for platoon or division firing, their target is 6 feet square: besides these, a moveable one, to practise at objects crossing, is constructed by placing one of the ordinary kind upon a low truck on iron wheels, which, by ropes on each side, is drawn to and fro in front of the men firing.

From the foregoing remarks, we are led to the conclusion that the arms and ammunition used by the Army are susceptible of improvements, and that appropriate places for the purpose of practice in firing are greatly wanted at many of our military stations.

The principles of aiming; and rules for instructing the soldier.

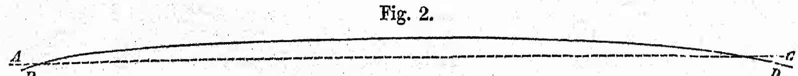
In considering the principles upon which the theory of aim with fire-arms is founded, it must be borne in mind that projectiles, when expelled from the barrel, are, in addition to the force of projection, affected by the power of gravity and of atmospheric resistance: the first of the two latter tends to lower the shot, the second to diminish its speed: as it therefore progresses, it gradually descends from the plane in which it was fired, in doing which, it describes a curve which, by degrees, descends to the lowest plane it meets, commonly the surface of the earth. The line of the axis of the musket, which is the direction which the shot takes, forms with the level of the sights, or the line of aim, a small angle, which arises from the greater thickness of metal at the breech (as shewn in fig. 1): in the infantry musket this angle A B C is about 22 minutes: thus the shot, following the axis of the bore, intersects the line of aim almost immediately on its leaving the muzzle: in the gradual descent which it afterwards makes (as shewn in fig. 2), it again intersects the line of aim. The distance at which

Fig. 1.



A C, line of aim.
B D, line of bore.
B, intersection.

Fig. 2.

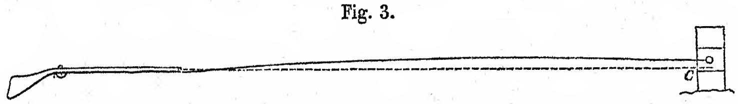


A C, line of aim.
B D, curve of shot.
D, second intersection.

the second intersection takes place from the muzzle, viz. from A to D, is the point-blank range according to the French interpretation, and which is more practically

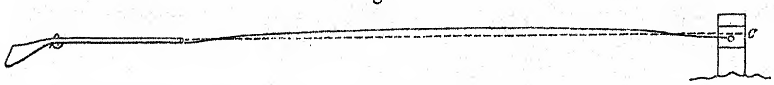
applicable to musket firing than the English acceptation of the term point-blank, being the distance at which the shot would strike on a plane the height of a man firing, or about 4 feet 6 inches below the level of the one in which it was fired, or a horizontal plane which would pass through the feet of the firer: according to the first rule, the distance for the infantry musket is 150 metres; according to the second, it is 75 yards. In order to strike an object at the point-blank distance of 75 yards, it is therefore necessary to aim straight at it: when the object is within the point-blank, it is apparent that as the shot, when it has traversed the distance, will be yet above the line of aim, the musket must be directed lower than the point aimed at (as at C, fig. 3): when the object is beyond point-blank distance, as the shot when it reaches

Fig. 3.



it will have descended below the line of aim, it must be directed above the point aimed at (as at C, fig. 4). These relative depressions and elevations must be in proportion to

Fig. 4.



the distances; 75 yards being the point-blank range of the musket according to repeated trials; though as arms will in some degree vary, the soldier should be taught to endeavour to judge for himself the point-blank of his musket. It is evident that at all objects nearer, the aim must be depressed; and at all further off, it must be elevated.

Levels of aim according to distance.

From numerous experiments made, the following degrees for different distances are found to be sufficient, viz.

At 50 yards, aim	. . . .	3 inches below the mark.
75 ,,	. . . .	straight at it.
100 ,,	. . . .	6 inches above.
150 ,,	. . . .	2 feet above.
200 ,,	. . . .	5 feet 6 inches above.
250 ,,	. . . .	11 feet above.

To simplify the directions given to the soldier, in firing at a human figure, they may be indicated as follows:

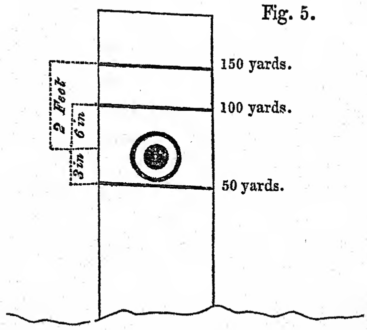
At 50 yards, aim	. . . .	at the thighs.
75 ,,	. . . .	,, waist.
100 ,,	. . . .	,, chest.
150 ,,	. . . .	,, head.
200 ,,	. . . .	,, height of a man above the body.
250 ,,	. . . .	at twice the height of a man above the body.

Of the vertical line of direction.

The above refers to the horizontal level of aiming; the vertical line must also claim some attention: the musket should be so held that the lines of fire, or of the axis, and of aim, be both contained in the same vertical plane; or, in common expression, that it be kept upright, not inclining outwards to the right or left, by which the true direction of the shot would be affected. The above outline of the principles of aiming will serve to shew the soldier, if well explained to him, how much will depend on a close observance of them. If the different degrees of level of aim, according to

the distance, were marked upon the target, similar to the French one, it would

Fig. 5.



be of great assistance: they might be arranged (as shewn in fig. 5) so that in practice at the target, the eye has a constant means of guiding it as to the degrees of elevation or depression: for men who have become good shots, however, the plain target ought to be practised at.

Deficiencies in practice with the musket, and the causes of them.

Though the theory of aim and of firing is so conclusive, that, if carefully attended to, the shot should never fail of its mark, yet the various causes of unsteadiness in firing, and the unavoidable imperfections in the arms and ammunition, so affect the results of musket firing, that they require to be explained to the soldier, in order that he may, as far as possible, guard against them, and at the same time be made aware of the causes which sometimes, in spite of every care, interfere with the success of his shot: they may be classed as follows:

1st. Unskilfulness, and defective vision of the firer.

2nd. Imperfections of the arms, in the quality and preparation of the ammunition, and in the loading.

3rd. Untoward circumstances affecting firing, such as the state of the weather, the locality, &c.

Unskilfulness of the firer.

The successful result of firing with a musket depends so much on the steady, firm manner in which it is held at the moment the charge is exploded, that many men, from their nervous temperament and constitution, are not capable of ever firing accurately: an imperfect sight, or rather incorrect vision, may also wholly deprive a soldier of the power of aiming; and both these causes are almost incapable of correction.

Imperfections in the arms and ammunition.

In the construction of the arms, the principal defective points are the incorrect positions of the sights, and the large allowance for windage. When the former are so placed that the line between them is not in the same vertical plane as the axis of the barrel, the aim directed by them will not theoretically correspond with the line of fire, but will incline either to the right or left; and the best method of remedying this result, if the sights are not re-adjusted, is to point the musket accordingly to the required direction; and when muskets are found invariably to carry to the right or left, it may be concluded that it is in consequence of the incorrect position of the sights. The difference between the diameter of the shot and the calibre of the barrel, called windage, though indispensable to admit of loading after much firing, is injurious to the correctness of the aim: its effects on the movement and direction of the ball may be best imagined by the consideration that the shot, after loading, will rest by its weight upon the lower side of the barrel, leaving the whole windage between it and the upper side, instead of being, according to theory, in the centre of the bore. As soon as it is acted upon by the expansion of the gunpowder, the effect of the powder forces it against the lower side of the barrel on which it is resting, which causes it to bound thence against the upper side, whence it rebounds to the lower, and so continues until it finally escapes, when the last of these successive bounds in a great measure decides the direction of its flight. In regulating the proportion of the size of the shot to the calibre of the musket, the windage should be reduced to the smallest which will admit of loading.*

* A small allowance of windage to a musket of 3′ 3″ in length will prevent rapid firing as the barrel becomes foul.—*Editors.*

The recoil, an unavoidable consequence of the nature of fire-arms, also materially affects the direction of the shot, unless the firer neutralizes it as much as possible by placing it firmly on the shoulder.

On the quality and preparation, on the quantity of the powder, and on the true form of the bullets, a great deal also depends: the former may be affected by the state of the atmosphere, or the place it has been stored in: in the latter, the deviations from the spherical form, and the centre of gravity not corresponding with the centre of the figure, will cause imperfect results.*

Other causes of deviations in firing.

The wind, and the position of the sun, in a great degree affect musket firing: when the former blows from the right or left, it will throw the shot in the contrary direction: if it blow in front, it will cause it to fall low; and if from behind, to rise. To remedy this cause of error, which is greater according to the distance, the means are readily apparent, and must be judged of by men firing: the effect produced by the sun, if it shine brightly, is to deceive the eye with respect to the sights: one side being in shade, the effect is to turn the aim to the right or left.

When the difference of horizontal level of the person firing, and the object aimed at, is considerable, the point-blank distance is in some degree altered; that is, in firing up from low ground, the force of gravity affects the projecting power more, and diminishes the point-blank, so that the aim must be more elevated accordingly: in firing down from a height, the same force increases the projecting power, and consequently makes the point-blank greater: it then is necessary to aim lower than usual.

The foregoing rules for aiming, and a notice of some of the causes affecting good firing, are thus briefly detailed, but they may be much more practically enlarged upon in explanation to the soldier, who, combining them with the practical use of his musket, will learn to value the knowledge of its real use and effects.

Instruction for young soldiers in firing.

This most essential part of the soldier's instruction cannot engage too much attention, and it should become the object of the greatest solicitude, as soon as the recruit has, in some degree, got through the elements of his drill without arms. The young soldier should be early impressed, that to fire with correctness and precision, and to use the weapon with which he is armed expertly, is the most indispensable part of his training; all movements, and marching, being merely the means of bringing him into a situation to execute this with effect; and as a desire to be considered skilful in the use of fire-arms is not only an object of emulation with soldiers, but with all classes of people who are acquainted with their use, the incentives of competition, and a wish to excel, may be brought to assist mainly in conveying the instruction in it, which will thus render it more simple, and considerably easier to the recruit, than the tedious monotony of his drill. The first instruction in the method of aiming should be well and clearly given to the soldier, and the latter made the subject of daily practice with his musket, before he is allowed to fire a round: his own barrack square, or even a passage, or a room, will afford space to initiate him in it. Instructors, specially for this branch, ought to be selected from the non-commissioned officers who understand the subject best, and are themselves good shots; and an Officer for each regiment, under whose superintendence they would act, and who should be fully competent to convey and overlook the instruction, would assimilate the system in some measure to gunnery instruction in the Navy. In the first lessons, no instructor should have more than five men to teach, as he can only deal with one at a time; and rests of some description, for the purpose of verifying the aim taken, should be used. In explaining to the recruit how to take aim,

* Probably, now that the balls are made by compression instead of casting, they are more perfect.

which may be done either at a target or any spot marked upon a wall, the principal directions are, relative to closing the left eye, to hold the firelock upright and steady, looking along the level of the sights on the barrel to the object aimed at: sometimes he will find it difficult to close the eye, but constant practice and trial will generally bring him into it. The instructor must be careful to examine the aim taken each time, and point out any incorrectness: at first, the distance should be short, 20 or 30 yards, and the same practice should continue until he aims well at the object, when he may then be gradually advanced to longer distances, up to 100 yards; the lessons being accompanied by an explanation of the principles of aiming at point-blank distance and at shorter and longer ranges, the elevations and depressions required, &c.

First practice of the recruit.

The recruit may then proceed to the practice-ground, and for the first five lessons will only take two rounds of ball-cartridge; so that the greatest care may be devoted to the firing. The instructor must fully explain to the men how important it is to load the musket properly; that is, to shake the powder sufficiently loosely into the barrel to charge the nipple well: the immediate and effective ignition of the powder, and the departure of the shot from the barrel, depend in a great measure on this: also to ram the ball well down upon the cartridge, but yet not to strike it so with the ramrod as to indent it, and damage its spherical form. The first efforts of the recruit should be to practise at a short distance, and upon a rest, the success of his first attempts tending so greatly to encourage him: his removal to fire at a greater distance can best be judged of by the instructor, but it should never be until he can hit the mark with both shots; and it ought then to be most gradual, never increasing more than 10 yards each time: in this way he may continue to increase to 100 yards, and when able to fire well at that distance, will be considered fit to take his place among the proficient soldiers at their practice. If the allowance of ammunition for the recruit be all expended before he qualifies himself to be thus dismissed, he must remain in the instruction class until the next season's practice: if it be not all expended, he may fire the remainder at the ordinary practice. By accompanying the first practices of the soldier with explanations of the principles and rules of aiming and firing, and also of the causes of uncertainty affecting them, he will acquire the theory and practice of his arm at the same time, and thus be disposed to take a greater interest in it.

In first firings, the recruit should certainly use a rest, in order that he may have no difficulty to contend with, except the right direction of the musket: as he improves, the instructor may judge when he may fire without a rest; and when he does so, should impress upon him the great importance of holding the musket with such ease that the muscular system may be, as nearly as possible, at rest; as, if not, the vibrations of the body must greatly affect the aim: the trigger must be pulled without jerk, and the breathing restrained at the moment of firing. All these minute points cannot be too much dwelt upon in the recruit instruction. Under a gradual system of instruction such as this, every recruit might, during the usual period allowed for his drill, if it happen during the season for practice, become qualified to take his place amongst the rest of his comrades. When dismissed from it, which it is better he should not be until he has fired twenty rounds, he would join the 3rd class.

System of classifying soldiers for ball practice.

The faculty of firing well, or using with accuracy a weapon which requires entire sympathy between the eye and hand, is not equally possessed by all men; in the nature and constitution of every one there is some difference which affects this quality: in any large body of men, considered as marksmen, there will be found some of all kinds,—good, middling, and indifferent. In considering what is good firing for soldiers with the musket, such as they are armed with, it will be found that in the practice of most regiments of the line, one-half, or 50 per cent. on the number of

rounds fired, is very good practice; but less would probably be the average: in the French 'Manuel du Tir,' 45 per cent. at 100 yards, 31 per cent. at 150 yards, and 20 per cent. at 175 yards, are given as good, or an average of 32 per cent. at all ranges. But in order to establish a high standard of perfection, it is suggested, that for all men firing up to 100 yards, 50 per cent. be considered good; up to 150 yards, 40 per cent.; and all beyond, 30 per cent.: in regulating, therefore, the classes for target practice, it must be established that no man be advanced to a higher class until he shall at least have made the number of good shots according to the foregoing scale. The distances of the different classes to fire from would be—

1st class, at 150 yards and upwards.
2nd do. at 100 yards and upwards, to 150 yards.
3rd do. under 100 yards.

All recruits, on joining from the instruction, would first fire in the 3rd class; and the gradual advances, though more rapidly made for first-class men, ought to be at short distances for the others: for instance—

3rd class, from	. . . . . .	50 to 60 yards.	
„	. . . . . .	60 to 70 „	
„	. . . . . .	70 to 80 „	
„	. . . . . .	80 to 90 „	
„	. . . . . .	90 to 100 „	2nd class.
2nd class, from	. . . . . .	100 to 115 „	
„	. . . . . .	115 to 130 „	
„	. . . . . .	130 to 150 „	1st class.

1st class, to advance 25 yards each time.

The rule for advancing to a greater distance should in the first instance be, to make the proportion of hits already given as the average of good firing in each class, viz. 1st class, 30 per cent., or 3 out of 10; 2nd class, 40 per cent., or 4 out of 10; 3rd class, 50 per cent., or 5 out of 10; and when each man in his respective class completes this number before the ten rounds are fired, he should fire the remainder at the longer distance to which he is advanced: for instance, a man of the 2nd class, firing at 80 yards, hits 4 out of 6,—he should then fire the 7th round at 90 yards. When the firing has in some degree improved, and the system of a gradual advance, according to firing, has been established, a more elevated rate may be adopted, viz. 1st class, 3 out of 5; 2nd class, 3 out of 4; and 3rd class, 4 out of 5. As ball practice ought, as much as possible, to be rendered an object of interest to the soldier, in order that he may view it as recreation, it should be done, as much as can be, without the restraint or form of parade: he will then take an interest in it, and go to it with more good will. Instead of large bodies, or entire companies, the men should be in small parties, so that it may not occupy too much time. If the practice-ground be near their quarters, they should be allowed to go to it without their accoutrements, which are cumbersome, and in their own way, and with full liberty to wear old clothing. Each party ought not generally to exceed 10 men, with 5 rounds per man, and be under the superintendence of the instructing Officer: this quantity of ammunition, 50 rounds, if every shot is carefully fired, and correctly registered, will take quite long enough to get through without becoming tiresome. When a squad is marched to the ground, the Officer in charge of it will ascertain the exact distance at which every man is to fire, and see that the target is correctly placed, and the distances marked: every man will fire individually, and do so in any position he chooses, standing, kneeling, or lying down, and with or without a rest: the result of each shot to be carefully observed before the next man fires. At the end of the

Squads for ball practice.

practice the Officer will make a report of the result, shewing how every missing shot went, and what men are qualified to be advanced. The greatest distance to which a man may fire, according to the foregoing system, ought not to exceed 300 yards; but a small number will be found to reach this. When men have evidently attained their best in firing, they may be expected to do the same, dressed and equipped in marching order, as in the ranks, and without any rest, the bayonet being fixed. The art of firing having been acquired in the most unrestrained freedom of movement, it will soon follow in the more encumbered position of the soldier. Though the important object to effect with the soldier is to accustom him to aim and fire correctly in the ranks, surrounded by his comrades, when the noise and excitement all tend to disturb his coolness,—and consequently some portion of the ammunition must be devoted to this practice,—it will be found, that long and continued individual practice is, in reality, the method of forming good shots: the man is then able to use all his skill and steadiness; and thus, once become a good marksman, will soon display the same in the fire of large bodies.

Firing by platoons two deep.

In firing by platoons or divisions two deep, the soldiers are placed under the most difficult circumstances, particularly those of the rear rank: the eagerness to be first, distracts the effort to aim, and men are frequently observed to fire before the musket is up to their shoulder, or they have any power of aiming.* The steady direction of the Officer, or non-commissioned officer, is then required to see that every man takes time to aim and fire: the results of such volleys ought always to be observed, and reported; a large-sized target to be used for it.

Another form of practice is also useful, to shew how the soldier can fire as light infantry in extended order: several targets are ranged at distances apart; a line of skirmishers being drawn up opposite, at 200 or 250 yards, they then fire, occasionally halting and advancing, each file taking a target, the result being also accurately registered.

Ball practice, if thus conducted, becomes very incessant, as, to get through the ammunition of a season, must occupy several weeks, or even months; but it thereby holds the important place it deserves in the exercise of the soldier, and instead of being dismissed in a few hurried firings, it is a daily subject of attention from all ranks. To encourage the efforts of the men to fire well, a system of small prizes, or distinctions, is most useful; and a preference to the latter, in the shape of a small medal or cross, joined to a pecuniary recompence, has been found to answer:† also, to put it on the footing of a challenge prize, requiring to be contended for two or three times, tends to keep up the spirit of emulation. Instead of giving a reward to any man who may chance to fire well on a particular day, or to hit the bull's eye, the firing of every man on the season's practice should be compared, and the best shots decided by it; the end of each season being considered the time to give the prize.

Rewards for best shots.

The registers of the ball practice ought to be carefully kept, and it would be more complete if every regiment had a regimental practice-book, in which the total results of the several companies' firing were entered, shewing their relative efficiency.

During the period of ball practice, the daily reports of each company's firing

* The propriety of giving the word 'Fire' to a body of men, firing simultaneously, is a point of discussion: the present practice of the Service forbids it; but in some trials made at Toronto, in Canada, in 1847, under the late Colonel Sir Charles Chichester, 81st regiment, the result was eminently in favor of giving it: in the fire of 18 files, 32 shots went into the target, with the word 'Fire;'—without it, about 11.

† A small silver cross for the best shot in each company, inscribed with the words 'Best Shot,' and one penny a day attached to it; and a medal, with two-pence a day, for the best one in the regiment.

ought to be recorded in regimental orders, to keep up the spirit of a desire to excel.

Of judging distances.

In addition to the qualification in firing, a very indispensable part of the soldier's training is the power of judging, in some degree, the distances of objects from him: it must be explained to him that this is one of the difficulties he will have to contend with in firing at an enemy in the field, and to what errors an ignorance of it may lead; and the Officers, who from their position in the ranks are more at liberty to attend to this than the men, must give their attention to it, so as to be able to point out the distance to them.* In order to practise men at it, the subject may be taken in two ways, and by constant repetition will soon give them some ideas upon it:

1st. It being understood that objects diminish, apparently, in size as they are farther removed from the eye, the man will be taken to the ground, and a certain distance being measured, he will be told to observe the apparent height of a man at it, or of any other object, at the same time being told how many yards they are off: this practice to be repeated frequently, and at various distances: the men should measure the distances themselves by pacing, the average length of each man's walking pace having been ascertained by trials on any given measured length.

2ndly. When the first practice has been repeated several times, the man may be called upon to judge the distance of any other which is unknown to him, which he must do by comparing the size as it appeared to him in the first method: the distance judged should be then measured in his presence, and the error pointed out.

These instructions may be varied, and on the same principle given, in such a way as to lead the man to judge pretty accurately the distance at which he has to fire.

Conclusion.

It may, then, be considered to have been satisfactorily shewn—1st, That the real efficiency of the infantry of an army must largely depend upon the degree of perfection to which they may have been brought in target practice. 2ndly, That such perfection is only to be acquired by a long course of instruction, based on scientific principles, and carefully carried out by the Officers and non-commissioned officers appointed for that purpose. 3rdly, That although it be denied to every soldier to become an expert marksman in an equal degree, it is yet perfectly possible, by strict attention and a methodical system of training, to bring the skill of most men up to a very fair average. And, lastly, That to remove the reflection hitherto cast on the inefficiency of the musket,—that the small proportion of 33 out of every 300 shots fired in action take effect,—it remains but to make all other drill and instruction for the foot soldier secondary to his education as a marksman.

However excellent may be the tactical proficiency of troops,—however admirable their steadiness under arms, and their celerity of movement in presence of an enemy,—their efforts must be diminished, if accompanied by a marked inferiority in the effect of their fire; for, in proportion as a calm and well-aimed fire, directed upon an advancing force, will tend to throw it into disorder, if not disperse it, so must a vague and ineffectual one serve to encourage its advance; and the very noise and confusion of such a useless discharge will throw disorder and hesitation into the ranks of the body which makes it.

It is, therefore, of the highest importance, that ball practice should be the first, as it is the most essential, element in the instruction and training of infantry soldiers.

APPENDIX.

The following rules for ascertaining distances in firing with ball were adopted by Captain Barry, Royal Engineers, in the instruction of his company (the 18th) of Royal Sappers and Miners at Portsmouth, in the summer of 1849.

* See Appendix.

For the Carbine.

The soldier was shewn, that if he covered a man from his feet to his breast with the muzzle of the carbine, that the person would be 80 yards distant,—and if covered to the top of the chaco, it would be 100 yards,—the piece being held to the shoulder.

For 140 yards, the rammer head of the carbine will cover a man, and at 180 yards the screw of the muzzle will do the same.

In taking these means of judging distances, it will be found convenient to hold the carbine a little on one side, to bring the object to be fired at in line with the portions of the carbine assigned.

For the Musket with the Bayonet on.

At 75 yards the blade of the bayonet covers a man from his feet to his face.
100 „ the bow covers a man to his waist.
150 „ „ „ chin.
200 „ the swivel-screw will do the same.

The Musket without the Bayonet.

At 75 yards the rammer head covers from his hip to his chin.
100 „ to the tuft of the chaco.
150 „ the rammer head covers from feet to face.
200 „ the swivel-screw covers a man from his feet to his chin.
250 „ the sight will cover a man from his feet to his shoulder.

The Regulation Rifle.

At 100 yards the sword bar will cover a man from his feet to his shoulder.
150 „ the same will cover to the tuft of the chaco.
200 „ the swivel-screw head will cover a man to his shoulder.
250 „ the same will cover to the tuft of the chaco.

These conventional means of judging of distances are so simple and so easily taught, or any other of a similar nature substituted, that it only requires a little practice to teach the men how to regulate their fire as regards the necessary elevation and depression of the piece; and the men of the 18th company of Royal Sappers and Miners, after one lesson with their inferior weapon, were soon able to hit a target, 6 feet square, every time, at 84 yards;—at 114 yards they put in six-ninths of their shots, judging the distance by the preceding rules.—G. G. L.

OBSERVATORY, ASTRONOMICAL.

PART I.*

The purposes which it is intended that an Observatory shall fulfil, and the magnitude and description of the instruments with which it is designed to be furnished, will, as a general rule, regulate its plan and dimensions.

Observatories are either permanent and of solid structure, destined for the taking and recording of observations which may be of fundamental or general interest and inquiry; or temporary and portable, having principally for their object observations for local and particular purposes.

Considering, in the first place, 'Permanent Observatories,' a matter of primary and most important consideration, before proceeding with the construction of a design, will be the selection of a fitting site. This should be on an eminence, not greater than is sufficient to command a clear view of the horizon to the north and south, and over

* By Captain M'Kerlie, R. E.

ground admitting of the erection, at suitable distances, of meridian marks in both directions; and it will be an additional advantage should the view be uninterrupted all round. The more solid and dry the nature of the soil is, the better; and it is essential that the site should be remote from all thoroughfares, particularly if for carriages.* The vicinity of swampy grounds, from which exhalations might arise, and of factories or other works, from the smoke of the chimneys of which annoying interruptions might be caused, should also be avoided.

The plan of arrangement of the building which has generally been adopted, and which is probably the most convenient, is to place the rooms intended for meridian instruments—viz. the transit, transit circle, and meridian or mural circle—in the centre, their transverse dimensions being truly perpendicular to the meridian line; whilst the rooms for instruments adapted for observing out of the meridian,—viz. the 'altitude and azimuth' and 'equatorial' instruments,—requiring rotative forms and a more commanding elevation, may be placed on the flanks. (See Plates I. II. III. IV.)

The dimensions and requirements of the several apartments will be noticed under the heads of the instruments for the reception of which they are intended.

The computing or waiting and attendants' rooms may be attached as wings, or perhaps more conveniently placed in the centre separating the meridian instrument rooms, where there is more than one. In these, fire-places may be constructed, which the necessity of maintaining an uniform temperature, and preventing draughts, render inadmissible in the observing-rooms.

Should the observatory be a national one, or of such important character as to require the constant and immediate presence of the observer, his residence may be attached as a wing, care being taken that its elevation does not break the sweep of the extra-meridional instruments.

In regard to the structure itself, of whatever material the circumstances of the locality may necessitate its being built, solidity and dryness should be the conditions sought to be attained. The foundation of the walls should be carried, if possible, as low as the bases of the piers of the instruments which they envelope: a stratum of asphalte should be placed at a sufficient distance below the floor wall-plate, to admit of a thorough system of ventilation being carried under the flooring; and above that level the external earth should not be allowed to touch the walls, but kept from them, if necessary, by a small covered area.

MERIDIAN INSTRUMENT ROOMS.

The Transit.—The purpose of the transit instrument requiring as a principal condition that it shall move in the plane of the meridian, the room destined to contain it will necessarily be placed rectangularly thereto; and its dimensions will necessarily be regulated by the size of the instrument.

In first-class observatories the focal lengths of the transit telescope object-glasses vary from 5 to 10 feet: the more ordinary length, however, is from 4 to 7 feet; that at the Royal Observatory, Greenwich, being the only existing one of the latter dimensions. For the 5-feet instrument the apartment should not be less than 18 feet by 15; for the 7-feet, 22 feet by 16, the longer dimension being in the direction of the meridian; and the height may be from 14 to 16 feet in the centre.

The utmost attainable immobility is essential to obtain the best results from the

* The public road passes close to the Royal Observatory at Chatham, and the noise caused by a cart rapidly passing is such as to render the beat of the clock inaudible; and the vibration caused by even a small party of men, in marching by, is such as to destroy the reflected image of a star in the mercury.

transit instrument, and the pier carrying it, constructed of solid masonry, should be based at such a depth as may be necessary to insure this condition. All the earth between it and the external walls should be excavated and removed, none being suffered to rest against it, and the floor must not be permitted to be in contact. The best supports for the ends of the axis are solid stone prisms, of such a height above the floor as to enable the observer, reclining on his observing chair, to note the transit of stars in or near the zenith; and they should be selected, not only from the same quarry, but, if possible, cut from the same block.

The smaller class of transit instruments, those varying from 2 to 3 feet in length, are more generally considered as portable instruments, their chief purpose being to obtain exact time, whilst the larger instruments are principally employed in determining, with minute accuracy, the positions in right ascension of heavenly bodies.

These smaller instruments are usually mounted on cast-iron standard frames, supported on piers of stone;* but when permanently fixed, it would be desirable that even they should be mounted in the manner of the larger instruments, the tops of the supporting pillars being corbelled inwards (on account of the shortness of the axis), to afford room for the observer to pass between and beneath. The dimensions of the room for instruments of this class may be 12 or 13 feet from north to south, by 10 or 12 feet in breadth.

The indispensable accompaniment of the transit instrument is the astronomical clock. Its value depends on the regularity of its vibrations; and to secure it against external influences, it should be carried on a solid and independent stone pier, sunk to the same level as the basis of that which carries the transit itself. The best position for the clock is on the south side of the transit-room, and on the right hand of the observer, looking south.

To admit of the transit telescope being directed to any part of the meridian, an opening in its plane is required in the roof, and to be carried down through the side walls to a little below the level of the axis of the instrument. In order to bring the temperature of the internal as speedily as possible to that of the external air, and to prevent in-draughts, this opening, for the larger instruments, should be about 2½ or 3 feet in width. The shutters to close it may be in two or more lengths, according to circumstances, and constructed so as to slide either entirely over the opening, or to meet in two pieces in the centre, motion being communicated from below by a winch and cordage; but in either case, most careful workmanship and an ample lap are necessary, to prevent leaking at the junctions. The vertical shutters, in one or more pieces, may either slide, or revolve in the ordinary manner on hinges.

For the smaller instruments, the aperture need not exceed 18 inches in width, and the shutters may be constructed to turn back on hinges, in the manner of the lid of a box. They will, generally, be most conveniently arranged in two pieces, meeting at the apex of the roof, thus admitting of the half on that side from which the wind blows being closed, and of observations being taken on the opposite side, which might otherwise be attended with difficulty; though, where the whole length does not exceed 10 or 12 feet, the fall being in one direction, the shutter may be in a single piece, with the advantage of being free from the liability to leak immediately over the instrument. In the Chatham Observatory the shutters are readily opened by means of a hook and ball, at the end of a short pole, fitting into an eye on the

* Much inconvenience, if not difficulty, is found in observing transits near the zenith with the Chatham 30-inch instrument, which is mounted in this manner. The proposed mode of mounting is shewn in Plate V.

Plate VI. figs. 1 & 2. inside, and are kept open by sliding the foot of the pole into a socket screwed upon the window sill, and the vertical cut is very conveniently combined with the windows. The roof itself, covered with lead or zinc, ought not to have a greater fall than is necessary to carry off the rain; and the windows should, in the northern hemisphere, be placed on the north side of the room.

The Mural Meridian Circle.—This instrument, the use of which is to measure angular distances on the meridian, either with reference to a fixed horizontal or polar zero, is supported on the larger end of a strong conical axis, bearing in collars or Y's fixed in a semi-cylindrical hollow cut in the mass of a solid stone wall or pier, placed with its length north and south; and close and parallel to one face of which (generally the eastern) the circle is required to revolve steadily in the plane of the meridian. To the face of the pier, also, are attached the micrometer microscopes for reading the graduated ring.

The same conditions of solidity of basis and of material, and of perfect insulation, are required for the pier of this, as for that of the transit instrument. The dimensions of the pier, above the floor-line, for the Greenwich mural circle, which is 6 feet in diameter, and may be considered as the standard in size, are 7 feet in length, 10 feet in height, and 4 feet in thickness. It is composed of four solid stones laid flat, one on the other, and from the under side of the third stone is cut the groove to receive the bearings of the axis, the steadiness of which, at the height of about 5 feet 6 inches above the floor, is thus secured by the heavy superincumbent mass. The mural circle is not adapted nor intended for transit observations, though attempts have been made so to apply it; but a good clock is a necessary appendage to its use, particularly when placed in a separate room, which it ought always to be. The size of the room, and also the arrangements as regards the opening in the roof, the shutters, &c., should be the same, nearly, as those for a transit instrument of the same length of telescope.

The Transit Circle, combining the properties of both the transit and the mural circle, and requiring but one room and a single observer, may be employed to answer the purposes of both these instruments, requiring, each of them, separate rooms and observers. This instrument, carrying a transit telescope within a strongly framed and braced double circle, is supported by a double-coned axis, resting on a pair of stone pillars in the manner of a transit instrument. The same precautions are required as for that instrument, and the same arrangement of the room and roof. A transit circle of the diameter of 6 feet, understood to have been cast in one piece, and most strongly braced, is now being fixed in the Royal Observatory, Greenwich, and the micrometer microscopes, for reading the graduations, are placed within a narrow circle on the outer face of the western pier, radiating through holes bored in the stone to their respective points on the limb; an arrangement which combines great stability in the microscopes with much convenience to the observer.

With the smaller transit instruments, such as are considered portable, a meridian circle of 10 or 12 inches diameter, with a graduated level, is sometimes combined, admitting directly of the determination of latitude as well as of true time.

The foregoing instruments afford the data on which exact Astronomy is founded: with those of them working in altitude, the observation of the barometer and thermometer is indispensable, as materially influencing the results, and they will therefore necessarily form a part of the furniture of their apartments.

The instruments now to be considered, with the apartments to be prepared for their reception, are those adapted for observation out of the plane of the meridian; and of these the first to be mentioned, on account of its importance, is the *Altitude and Azimuth Instrument.*

The construction of this instrument admitting of its being moved freely in azimuth, without materially disturbing its adjustments, provided it is firmly based, or injuring its property of giving accurate vertical measurements, its use is very comprehensive. When accurately adjusted to the plane of the meridian, which is its true astronomical position, it may be made to perform as a transit circle, giving right ascensions or true time, as well as altitudes and zenith distances, from which latter, latitude may be determined; though, with more correctness, from several observations near the meridian.

Time and latitude may also be obtained by observations in other positions of the instrument, as by absolute or equal altitudes or transits over the prime vertical, and the direction of the meridian line may also be very conveniently determined with it.

In the larger instruments of this description (the vertical circle of that in the Dublin Observatory being as much as 8 feet in diameter,—others of 5 and 3 feet), there are some differences in the arrangement of their supports, principally in the manner of steadying the upper pivot with which some of them are constructed. In the one recently erected in the Royal Observatory, Greenwich, the summit of the slightly tapering circular brick pier carrying it is spread out into the form of a tripod, on which rests a triangular frame of cast iron, forming the basis of a system of wrought rod-iron vertical triangles, crowned by a horizontal one, (the angles all uniting,) in the centre of which, formed by the junction of three bars radiating to its angles, is the socket to receive the upper pivot of the instrument. A solid circular block of stone, in the centre of this truss, carries the instrument, which is of great weight, solidity, and steadiness, and was especially designed by the Astronomer Royal for observing lunar altitudes out of the meridian. The diameter of both its vertical and azimuthal circles is 3 feet.

The smaller instruments, such as have 15-inch or 18-inch vertical and horizontal circles, and which are portable, and of very extended utility, are generally supported on foot-screws, three in number, resting in brass cups, either fastened on a masonry pier when in a permanent observatory, or on a wooden tripod stand when for temporary use in moving about. When mounted in a permanent observatory, the pier of support should be constructed with the same regard to solidity and insulation as has been before pointed out, and must be carried up to a sufficient height to admit of the instrument, when in place, having a complete command of the heavens over the transit-room, or other adjoining buildings.

For an 18-inch circle, the top of the pier may be 2′ by 3′ 6″, the larger dimension being placed north and south, to give space for a mercurial trough being placed for observations on the meridian by reflection. The form of apartment best adapted for the instrument is the circular, or at all events, such a form as to receive a circular curb to carry a rotatory dome; and as it is desirable that no unnecessary force should be required to put the dome in motion, the diameter should not be greater than the convenient working of the instrument demands. For an 18-inch circle, 10 or 12 feet will be sufficient; for a 3-feet circle, 14 or 15 feet.

The rotatory roof, or dome, may be either conical or spherical:* the former, however, is much the simpler and more economical construction, and the shutters can be much more easily applied to the cut which is necessary on one side of it, extending also about a foot or so across the apex. The upper part may be separately opened

* The roof over the Greenwich instrument is cylindrical, with a nearly flat top, and is 12 feet in diameter.

for zenith observations, and closed by a shutter in the manner shewn in figs. 1 & 2, Plate IV. The lower part may be conveniently opened and closed by a rod or hook, as shewn in figs. 3 and 4, Plate VI.; and as a means of increased lightness, these shutters may be covered with painted canvas, the rest of the roof being covered with zinc (as is the case in the Chatham Observatory) or copper. There are several methods of supporting the roof so as to obtain a circular motion, as on fixed rollers, on balls moving in square channels, or on balls running freely in concave channels, both over and under the balls. The second method is shewn by fig. 4, Plate VII., being that used for the altitude and azimuth room of the Chatham Observatory, but the last method is that which produces by far the freest motion. Fig. 2, Plate VII., shews the section of the channels, on this principle, of the 15-feet dome over the Chatham equatorial. The dome over the large equatorial telescope recently mounted at Cambridge by the Astronomer Royal, which is 26 feet in diameter, in form a flatter cone resting on the frustrum of a sharper cone, and framed of wrought iron braced with hoop-iron and covered with zinc, is also carried in this manner, and revolves with perfect freedom. Fig. 5, Plate VII., is a section of its channels and balls. The radius of the sunken surface may be twice the diameter of the balls, of which six is the proper number to employ.

To give motion to the smaller domes, not exceeding 12 feet in diameter, the force of the hand is sufficient, and may be applied either to pins or handles let into the inner face of the curb; or should that be inconveniently high, to a fixed handle brought down to a suitable position, (figs. 3 & 4, Plate VII.) For the larger domes, the application of levers and other mechanical contrivances to communicate quick or slow motion is required. Figs. 1 & 2, Plate VII., shew the form of the levers for the Chatham equatorial dome.

It may be a necessary precaution to secure such domes against liability to displacement in storms or gales of wind, and for this purpose, hold-fasts or other means must be employed, which there can be no difficulty in contriving.

The *Repeating Circle*, by Borda, is an instrument which, as it requires nearly the same accommodation as the altitude and azimuth instrument of the same size, may be mentioned in conjunction with it. The principal difference is, that the supporting pier must be somewhat broader, to give space for an illuminating lamp on a separate stand. The chief astronomical use of this instrument is to observe circum-meridian altitudes for latitude. Time may also be obtained with it by equal or absolute altitudes. Its perfect manipulation, however, demands two observers, and it is altogether an instrument but little known or used in this country.

The *Equatorial* is the next instrument for which provision of space, in a permanent observatory, is to be considered. The form and position of the supports of this instrument will depend on the nature of its construction, which is of two distinct kinds; one, in which the telescope is carried, with the declination circle, on a transverse axis at the end of, and at right angles to, a long polar axis; and the other, in which the telescope is carried in the manner of a transit, between the cheeks of a frame-work forming the polar axis, pivots being fixed in the centres of its extremities, and long enough to permit the telescope to revolve completely within it. A stone bed of a suitable length for the polar axis, and having its upper surface dressed to the degree of slope of the latitude of the place, may form the support, according to circumstances, of the first form of construction. The second form, admitting of both larger horary and declination circles, and having other advantages, is that most generally adopted in England. It is supported,—the lower pivot in a socket let into a stone bed, and the upper in a collar in a fixed metal frame-work. The use of this instrument is, to determine the place of celestial phenomena by reference to its gra-

duated circles. Great reliance cannot, however, generally be placed on the exactness of its results, unless used differentially. The same degree of perfection of stability in its supports is not, therefore, demanded, though this must still remain a point of importance. Like the altitude and azimuth instrument, the equatorial must be mounted high enough to command the heavens, and under a revolving roof.

The size of the instrument, and the form of its mounting, with a due regard to sufficient accommodation and the easy working of the dome, will regulate the diameter of the apartment.

When great optical power for astronomical investigations, for the observation of occultations, of eclipses, of Jupiter's satellites, or for micrometrical measurements of the planets, &c., is required, larger telescopes must necessarily be employed. These are generally equatorially mounted, and carried by clock-work, the graduated circles being, however, more for finding objects than for determining their positions; and when advantageous sites offer, they may be placed (as they frequently are) in isolated buildings specially constructed for them.

The instruments which have now been mentioned comprise all those with which modern observatories are ordinarily furnished. The *Zenith Sector* has not been referred to, as it is not understood to be now in use in any permanent observatory, and the recent construction of the instrument by the Astronomer Royal, for the Ordnance Survey, is considered more as of a portable character. The great reflecting telescopes, as Sir W. Herschel's, Lord Rosse's, &c., it is also unnecessary to do more than merely mention.

Portable Observatories now remain to be described. Their construction will differ according to the purpose of the instrument which they are intended to give cover to, and may be considered as of three classes; namely, for the altitude and azimuth instrument, the transit, and the zenith sector, the principal instruments which are portably employed.

For the first, (the altitude and azimuth instrument,) the observatory which was designed and used by Sir John Herschel at the Cape supplies all that can be required, and it also suffices for the transit instrument.

The observatory used on the Ordnance Survey for the first-class theodolites (described by Major Robinson, R. E., in Part III., and figured in Plates VIII. and IX.) may also, with a little modification in the roof, be adapted to this instrument when circum-meridian observations only are desired. For the other instruments, the transit and zenith sector, the observatories used on the Ordnance Survey (also described by Major Robinson, and illustrated in Plates XII. and XIII.) are very complete.

With these examples, then, there can be no difficulty in at any time designing for any particular instrument a portable shelter. It seems only further necessary to remark, that the floors of each of these observatories must be kept quite clear of the stand of the instrument, which, were it practicable, it would be desirable always to base on solid rock; but as this cannot often be the case, stout stakes should be driven, when possible, firmly into the ground, and the heads prepared to receive the feet of the tripod.

Although this paper was intended to have reference to the construction of Observatories only, and not to practical observing; yet, as it has been thought it might be useful to add some memoranda on this subject, the adjustment of such of the instruments as are most frequently met with, the corrections for residual errors, and the formulæ for the reduction of observations, are briefly touched on, and the forms for recording observations used at the Chatham Observatory are given.

The purpose of the transit, as has been stated, is chiefly to obtain true time, and to determine right ascensions. To this end it is necessary that the centre wire of the telescope should be vertical, and the line of sight through it perpendicular to the axis, or in collimation; also that the axis should be level, and the telescope revolve in the plane of the meridian. The instrument being brought approximately into position, the adjustments are completed by means of proper screws provided for the purpose; but perfect adjustment cannot be expected to be obtained, and remaining errors must be allowed for by computation.

For level, the striding level must be applied before and after each observation, and the difference between the sum of the east and the sum of the west readings being taken, then $\frac{1}{4}$ of that difference $\times \dfrac{\text{sin. alt.}}{\text{cos. declin}^{\text{n}}.}$ of star observed = the correction to be applied with its proper sign + or −; and as the scale of divisions on the level tubes are usually in spaces of $1\frac{1}{2}''$, the correction will be in 10ths of seconds of time.

For collimation, observe the passage of a star of very high declination over the 1st, 2nd, and 3rd wires, and again, in a reversed position of the instrument, over the 4th and 5th, which in the 1st position were the 2nd and 1st, noting the level readings before and after each passage: then the difference between the mean of the 1st, 2nd, 4th and 5th, and the 3rd, each corrected for level, is the error due to collimation; which error × by cos. declination of star observed is the collimation error or effect on an equatorial star; the correction for any other star = collimation error × secant of declination of that star. Attention must of course be paid to the signs.

For azimuth, transits of two stars, either on opposite sides of the zenith remote from each other as possible, or on opposite sides of the pole, but on the same side of the zenith, if each be near the pole, the more accurate, are to be observed. Then, the sum of the errors produced on the transits, (each corrected for level and collimation,) ascertained by comparison with the proper interval, will be the effect of azimuthal deviation. Calculate the result of 1^{s} azimuth error on each star = $\dfrac{\text{cos. alt.}}{\text{cos. declin}^{\text{n}}.}$, then the deviation = the observed sum of the errors divided by the sum of the two results. The correction for deviation for any star = $\dfrac{\text{cos. alt.}}{\text{cos. declin}^{\text{n}}.} \times$ by the deviation. The azimuth error may be obtained by transits of stars in other positions; in which case, however, it will be the difference instead of the sum of the errors on the interval. It may also be obtained by observing the transits of a circumpolar star at its upper and lower culmination; in which case, the difference between the observed interval and 12 hours will be the sum of the effects on the upper and lower transits produced by the azimuthal deviation. There are also other errors, arising from the intervals between the wires of the telescope being unequal, and also for inequality of pivots, which must be ascertained and allowed for.

In observing with the transit, whilst the star or other object is steadily viewed, the instant of its passage over each wire is noted by listening to and counting the beat of the clock; and the mean of the wires, corrected for the instrumental errors, is the true clock time of passage, the error of which is thus ascertained, and, by observations extending over several nights, its rate.

The form of registration used at Chatham is as follows:

Transits over the Meridian of the Observatory of the Royal Engineers' Establishment, Chatham.

No. of Observation.	Date.	Illuminated end, East or West.	Inclination of axis. E. end highest — W. end do. + : Indication of Level.	Inclination of axis: Inequality of Pivots.	Object.	Zenith distance.	North or South.	Telescope Wires. I.	Telescope Wires. II.	Telescope Wires. Centre.	Telescope Wires. IV.	Telescope Wires. V.	Mean.	Corrections. To Centre Wire.	Corrections. Collimation.	Corrections. Inclination.	Corrections. Azimuth.	True Passage.	Clocks. Error.	Clocks. Rate.	No. of Days.	Remarks.
	1849.		s.	s.		° ′		s.	s.	H. M. S.	s.	s.	H. M. S.					H. M. S.				
532	Jan. 22.	E. / W.	E.: + ·07, + ·02, + ·02; W.: + ·12, Level.	+ ·04 / } — ·04	Polaris.	37 5	N.	40-38	51-33	1 2 28	13-20	24-16										Collimation error deduced = 0s·038; + when illuminated end is East, and star above Pole.
533	,,	E.	— ·2	+ ·04	Aldebaran.	35 11	S.	12	30	4 25 47	5	23	4 25 47·4		— ·06	— ·13	— 1·39	4 25 45·82	— 90·71			
534	,,	E.	Level.	+ ·04	δ Orionis.	51 47	S.	16	33	5 22 49·5	6-5	23-5	5 22 49·7		— ·06	0	— 1·82	5 22 47·82	— 90·89			
535	,,	E.	— ·05, — ·15, — ·15, — ·1, — ·1	+ ·04	ε Ursæ Minoris.	46 20	N.	55-56	58-3	5 0 9	2-15	4-22	5 0 9		+ ·47	+ ·35	— 12·43	4 59 57·3	— 92·88			Below the Pole.
536	,,	E.	Level.	+ ·04	ε Orionis.	52 40	S.	31	48-5	5 27 5·5	22	39	5 27 5·2		— ·06		— 16·7	5 27 3·47	— 90·67	+ ·10	7	
537	,,																					

Note.—The forms here given, including the above, were arranged for the Chatham Observatory by Captain Harness, R. E., and the formulæ for corrections and reductions are also principally from his notes.

To ascertain the error of other time-keepers by comparison with the clock which is thus noted, a most accurate method is given by the Astronomer Royal in Part II., and the following is the daily form of reduction for error of a mean time chronometer at Chatham:

R. E. Observatory,
Jan. 24, 1849.

Clock's error $44^s{\cdot}41$ slow.
Rate . . . ·43 losing.

H.	M.	S.	
20	11	46·90	sidereal time at mean noon at Greenwich.
		·35	correction for longitude.
20	11	46·55	sidereal time at mean noon at Observatory.
17	13		clock at time of comparison with chronometer.
2	58	46·55	difference.
1	59	40·34	mean equivalents for above difference.
	57	50·49	
		45·87	
		0·54	
2	58	17·24	mean interval from noon by clock.
12			
9	1	42·76	mean time A. M. by clock.
9	0	95·	time by chronometer.
	1	37·76	chronometer slow.
		44·41	clock slow.
	2	22·17	error of chronometer, slow.

The reduction of observations will be considerably facilitated by preparing a table of corrections for 15″ or 1^s of each form of error for every $\frac{1}{2}$ or $\frac{1}{4}$ degree of declination computed to the latitude of the place; and it will also be found convenient to prepare a table of the true and apparent altitudes and zenith distances, as well as the right ascensions of the principal stars.

By observations of lunar transits in conjunction with the moon culminating stars which are given for each day on which the moon is visible throughout the year in the Nautical Almanac, longitude may be ascertained, accurately by direct comparison with corresponding transits over an observatory whose longitude is known, and approximately from the computed transits over the Greenwich Observatory, as given in the Nautical Almanac.

The transit instrument, when portable, may also be applied to obtaining latitude with considerable accuracy, by placing it in the plane of the prime vertical, or at right angles to the meridian. The observation for this purpose consists in noting the transit of a star over the prime vertical both to the east and west—then, the cos. of $\frac{1}{2}$ the interval in sidereal time reduced to arc, × by the cot. declination of the star, = cot. of the latitude. In order that the time-keeper may have but a short interval to measure, stars should be chosen for observation whose declination is but a few degrees less than the latitude, and the approximate altitude and hour-angle from the

meridian may be computed, assuming a value for the latitude, from the formulæ $\text{sin. alt.} = \frac{\text{sin. declin}^{n}}{\text{sin. lat.}}$. $\text{cos. hour-angle} = \frac{\text{cot. lat.}}{\text{cot. declin}^{n}}$. By reversing the instrument between the east and west observations, the error of collimation is counteracted, and a deviation of a few minutes from the prime vertical will not be of any material importance. The error in the level, therefore, need only be observed, producing a similar amount of error in the result.

The use of the Altitude and Azimuth instrument has previously been explained, and requires that the vertical circle and axis of the telescope shall in all positions of the instrument describe a great circle. The adjustments are—1st, To set the vertical axis perpendicular to the horizon. This is effected approximately by the ground levels attached to the lower circle, and more accurately by the graduated level hung to the arms carrying the microscopes, and by the foot-screws. 2ndly, The horizontal axis of the upper circle and telescope must be set level. This is done by passing the striding level between the bars of the circle, and reversing it. 3rdly, The micrometer microscopes must be brought into a diameter of the circle, and adjusted to distinct vision and correct measure of the graduations on the limb. 4thly, The optical adjustments of the telescope are to be perfected, and the central wire caused to describe a great circle; and finally, the micrometer microscopes are to be re-adjusted, and the error of collimation in altitude to be removed or ascertained.

It is not, however, to be expected that the errors can be entirely destroyed by adjustment. The indications of the level must be noted in reversed positions for all observations, and the error, = $\frac{1}{4}$ the difference of the sums of the readings (face of instrument right and left), allowed for; and in collimation, the errors both in altitude and azimuth may be eliminated by making the observation in reversed position, that is, with the face of the instrument both right and left, which should always be done when possible.

There are several methods by which latitude may be obtained by means of the altitude and azimuth instrument.

1st, By observing the greatest and least altitude of a circumpolar star. The mean of the observations, each corrected for refraction, &c., will be the latitude. In the northern hemisphere, Polaris and δ Ursæ Minoris are excellent objects for this purpose. 2ndly, By observation of the meridian altitude of any heavenly body whose declination is known; which is the method most generally adopted: and 3rdly, as the result of both the previous methods is dependent on the accuracy of a single observation, with greater precision, probably, by circum-meridian observations of a star or other object, that is, by taking several altitutes before, and an equal number after passing the meridian, and as nearly as possible at equal distances from it, noting the time of each. The instrument should be reversed between the eastern and western observations, thus destroying the effect of collimation error; and the observations should be limited to not more that 15 minutes on each side the meridian when the zenith distance exceeds 30°, and to not more than 8 minutes if less.

The correction to be applied to the altitude, or

$$\text{Zen. dist.} = \frac{\text{sin. co-lat. sin. Polar dist.}}{\text{sin. zen. dist.} \times \text{sin. } 1''} \times \text{vers. P},$$

in which an approximate value of the co-latitude is assumed, and the other quantities for each observation being the same, the mean of the versines of the hour angles (P) has only to be applied to the general formula.

The form of record for observations with the altitude and azimuth is as follows:

ALTITUDE AND AZIMUTH INSTRUMENT.

Observations on or near the Meridian of the Observatory of the Royal Engineers' Establishment, Chatham.

No. of Observation.	Date.	Object.	Approximate zenith distance.	North or South.	Direct or Reflected.	Face of instrument E. or W.	Readings.								Error of Time-keeper.	Barometer.	Thermometer.	Remarks.
							Time-keeper.	Level.		Microscopes.								
										A.		B.						
								Eye-end.	Object-end.		Corr. for Run.	Reading.	Corr. for Run.	Mean.				
			° '				H. M. S.			° ' ''	''	''	''	H. M. S.	s.	in.	°	

Latitude may be obtained also with this instrument by observations of the transits of stars over the prime vertical, as with the transit instrument, and also by observations of Polaris out of the meridian, of which latter method a description, with Tables, is given in the Nautical Almanac.

To obtain time with this instrument, two methods may be employed: 1st, by a single altitude on or near the prime vertical. In this case the latitude is supposed to be known, and the hour-angle, and consequently the time, is obtained from the formula

$$\sin. \frac{Z\,P\,S}{2} = \sqrt{\frac{\sin.\,(S - P\,S)\,.\,\sin.\,(S - Z\,P)}{\sin.\,P\,S\,.\,\sin.\,Z\,P}},$$

in which Z P S is the hour-angle formed by the meridian of the object and of the observer, P S the co-declination of the object, Z P the co-latitude, and Z S the co-altitude,

$$S \text{ being} = \frac{Z\,S + P\,S + Z\,P}{2}.$$

2ndly, by equal altitudes, which method is independent of the latitude, one-half the observed interval between the star attaining equal altitudes being the time of its passing the meridian, from which the error of the time-keeper becomes known. If the object be one whose declination alters during the interval, as the sun, or a planet, correction is necessary on this account

$$= \left(\cot.\,Z\,P\,.\,\text{cosec.}\,\frac{P}{2} - \cot.\,P\,S\,.\,\cot.\,\frac{P}{2}\right) d,$$

$\frac{P}{2}$ being = the half-interval corrected; but which may be assumed as half the observed interval, without sensible error, and d = the change in declination.

The direction of the meridian may be found by observing the greatest eastern and western elongations of a circumpolar star, the mean of the readings of which on the horizontal limb will be the reading of the direction of the meridian; also by observing the readings of the positions in which a star attains equal altitudes, and also by observation of a single altitude, when, the latitude being known, the azimuth angle may be computed.

In regard to the repeating circle by Borda, its principal astronomical use has been stated to be in observing circum-meridian zenith distances, or, by reflection, altitudes.

The adjustments consist in making the upright axis perpendicular by means of the main level attached to the back of the circle, and the plane of the circle vertical by the small cross level on the counterpoise end of its axis. The observations are made thus: the telescope is clamped by means of one of the arms carrying the verniers to the circle, and the object bisected by the slow-motion screw of the circle, whilst the bubble of the level is kept near the centre of its run, and its indication noted the moment the observation is complete. The verniers are then to be read, and the instrument turned 180° in azimuth, and the telescope, by unclamping the vernier-plate, is brought over the zenith, again clamped, and the object again bisected by the telescope slow-motion screw, whilst the level is again read. Twice the zenith distance of the object has thus evidently been passed over. The time of each observation must be carefully noted. This process may be repeated as often as may be thought fit, and the readings of the first and last observations only being taken, their difference divided by twice the number of repetitions will be the zenith distance, to which must be applied the correction for level, = the difference between the sums of the object and eye end readings divided by twice the number of observations, − if the object-end be the greater, and + if the eye-end. The following is the form for recording the observations:

REPEATING CIRCLE.

Observations on or near the Meridian of the Royal Engineers' Observatory, Chatham.

No. of Observation.	Date.	Object.	Approximate zenith distance.	North or South.	Direct or Reflected.	Face of instrument, Left or Right.	Readings.								Error of Time-keeper.	Barometer.	Thermometer.	Remarks.
							Time-keeper.	Level.		Verniers.								
								Eye-end.	Object-end.	A.	B.	C.	D.	Mean.				
			° ′				H. M. S.	″	″	° ′ ″				° ′ ″	s.	in.	°	

The only other instrument which will now be referred to is the *Zenith Sector*, constructed within the last few years for the Ordnance Survey. In determining latitudes in the field, its results are understood to have been highly satisfactory. Having been placed in the plane of the meridian, and the axis, which has three levels attached to it, made vertical, or nearly so, the observations are made by setting the telescope nearly for a star, reading the micrometer microscopes to the sectors, and then completing the observation by the wire micrometer attached to the eye-end of the telescope, at the same time noting the level readings and the time. The instrument is then turned half-round, and the observation repeated; completing the bisection on this side by the tangent-screw, again noting the levels and time, and lastly, the readings of the micrometer microscopes: the double zenith distance is thus obtained.

As it is conceived that in field operations they may be of great value, a part of the instructions which were furnished to the Officers of the Royal Engineers who were engaged in the survey and astronomical determination of points in the Boundary between the United States and Canada, in 1843–5, by the Astronomer Royal, are, with his permission, given in Part II. J. G. McK.

PART II.—ON THE PROPER MANNER OF COMPARING CHRONOMETERS AND OTHER TIME-KEEPERS.*

A. I. *General Rule.*

The most important of all things regarding the accurate use of transits and chronometers, is to acquire the habit of counting the beats of the clock, or the alternate beats of a half-seconds chronometer, without looking at its face while writing, or while moving about, or through any disturbance.

A. II. *To compare a solar half-seconds chronometer with a sidereal clock, by coincidence of beats.*

Place the chronometer on a stool or table near the clock; hold a memorandum-book in one hand and a pencil in the other. Listen carefully to both the clock and the chronometer, keeping the eye fixed on the seconds-hand of the chronometer.

The beats of the two instruments will at first, perhaps, follow in no distinct order; but as the clock gains on the chronometer it will be found that they approach the state of beating simultaneously. When you are satisfied that they are beating simultaneously, you must mentally *select* one of the beats which you assume to be perfectly coincident, (as the precise time will be doubtful during a few seconds,) and immediately write down that second (with its half-second, if it happens to be a half-second) in the memorandum-book, and at the same time begin counting the beats of the clock, 1, 2, 3, 4, &c. Then write the minutes from the chronometer face, and then the hour, (still continuing to count the beats of the clock,) and then turn your eye to the seconds-hand of the clock; continue counting till the seconds-hand is at a conspicuous place (the beginning of the minute or of one of the tens); and then stop. Write down, first the seconds that you have counted; secondly, the seconds on the clock face at which you stopped; thirdly, the minutes from the clock; and fourthly, its hour. Then the comparison will stand thus: chronometer, $1^h\ 16^m\ 22^s{\cdot}5$ = clock, $11^h\ 42^m\ 20^s - 27$, where 27 is supposed to be the number of beats counted from the selected coincidence.

In comparing a half-seconds solar with a half-seconds sidereal chronometer, the process is the same, counting every alternate beat of the sidereal chronometer.

A. III. *To compare a pocket chronometer beating five times in two seconds, and going mean solar time nearly, with a sidereal clock, by coincidence of beats.*

The second-hand of a pocket chronometer making 5 beats in 2 seconds, advances $0^s{\cdot}4$ at each beat. It will not, therefore, coincide at every second with a mark on the chronometer face, but at every alternate second. In order to see distinctly at which second the coincidence takes place, (so as to avoid the error of $0^s{\cdot}4$,) and also to correct the usual error in the division of the chronometer face, it will be expedient to mark the face with ink, correctly, at every alternate second.

Suppose, then, the face is either so correct as evidently not to require this, or that the correction is made by ink marks. Then the process of comparison with the sidereal clock will be exactly the same as that for a half-seconds chronometer. It will, however, be a little more troublesome, because there are always a number of beats at small intervals which disturb the ear, and because in most cases the chronometer time will be a fraction of a second which requires a little care; thus, if the chronometer reading be one which follows 26—it may be 26·4, 26·8, 27·2, 27·6 or 28, and hence four out of five are at fractions of a second.

* Selected, by permission, from notes by Professor G. B. Airey, Astronomer Royal.

The comparison of a $\frac{2}{5}$-seconds solar chronometer with a 2-seconds sidereal chronometer will be made in the same way, always counting the alternate beats of the sidereal chronometer, (as said before under No. II.)

There are some chronometers which beat 8 times in 3 seconds: with these it would be requisite to mark the face at every 3 seconds, and then supposing a coincidence to be at one of the beats following 21^s, it would be at $21\frac{3}{8}$, $21\frac{6}{8}$, $22\frac{1}{8}$, $22\frac{4}{8}$, $22\frac{7}{8}$, $23\frac{2}{8}$, $23\frac{5}{8}$, 24. This is therefore very troublesome.

(I.) *To adjust a portable transit instrument.*

1. As early as possible, correct very carefully the error of collimation, and make yourself quite sure that every screw about the object-glass and wire-frame is quite tight. This may be done by the use of any mark in any position, at a distance where it can be distinctly seen. The best mark will be a hole in a tin plate with a reflector behind it.

2. At the same time, by reversing the transit several times, and levelling carefully each time, ascertain whether there is any apparent irregularity of the pivots; and remember that half the apparent error is in future always to be left in the position to which the axis is raised.

3. As soon as stars appear, look for Polaris and direct the transit to him, taking care that the axis is very nearly level. With the time by account find his hour-angle east or west of the meridian; with this and the latitude by account find his azimuth at the observation. Bring the transit to a horizontal position, and let an assistant carry a lamp to any convenient distance, and move it (by signal) till it is under the wire; measure the distance roughly (as by pacing), and with this distance as radius, compute the value of the azimuth, and shift the lamp by this quantity, and fix it for a temporary meridian mark.

4. Direct the transit to this mark, and level it carefully; observe the transit of a star as near the zenith as possible, and you will have the correction of your chronometer to sidereal time very nearly.

5. With this correction compute the time when any of the near circumpolar stars ought to pass the middle wire, λ Ursæ Minoris, Polaris, 51 Cephei, ϵ or ζ Ursæ Minoris, or even γ Cephei, above or below the pole, (Polaris is the best;) and as the star approaches the wire, knowing the time in which it passes from wire to wire, you will be able to see whether it will reach the middle wire about the proper time. If it is likely to be so far from it that the adjustment screws will not bring it right, shift the feet of the stand immediately, (this must be done rapidly and steadily,) till it is very nearly right; then level the transit, and with the adjusting screws place the wire on the star at the proper time.

6. This may be done by degrees, by using different stars (as they pass successively) for successive approximations. For this purpose it will be convenient to have ready at hand, a table with the circumpolar upper and lower positions. Set down in the mingled order in which their upper and lower transits occur, with the R. A. for that day placed opposite, and another column in which the R. A. corrected for chronometer error may be inserted as soon as a zenith star has been observed.

7. While waiting for these circumpolar stars, if a low Nautical Almanac star should pass, its time may be prepared, and an endeavour made to plant the wire on it at the instant: but this is not to be done after a circumpolar star has been observed, because the circumpolar determinations are the more accurate.

8. As the successive corrections of position are made, observe any stars that pass pretty high, and you will get more and more accurate corrections of the chronometer for use with the next circumpolar star.

9. After every shift, level the transit carefully before using it for another star.

10. In this way you will in two or three hours get the transit into the meridian with scarcely an appreciable error remaining. When that is done, shift the temporary position of the meridian mark delicately, and even fix one at a considerable distance (by signal) exactly under the wire. You can then observe a few stars for chronometer error, and your transit may be considered as adjusted.

11. It will be prudent never to shift this mark again, but always to bring the transit upon it, and level carefully before every observation. Then consider the transit as having an azimuthal error Z.″ by which, when directed to the pole, it points too much to the west. Then prepare for all the stars which you are going to observe, small tables of the numbers—

$$\frac{\text{sin. star's zenith distance}}{15 \times \text{sin. star's N P D}},$$

negative between the zenith and the pole, and positive for other parts of the meridian.

By comparing the clock errors given by the transits of circumpolar stars with those given by any other, or even by comparing the clock errors given by zenith stars with those given by low stars, the difference of these clock errors (containing a multiple of Z.) will determine Z.; and then this value of Z., multiplied by the factor for each star, must be applied to the observed transit of that star.

12. In a favorable night, the transit should be reversed, and some transits of circumpolar stars and clock stars be observed with illuminated end east as well as illuminated end west, and the mean should be used. The collimation should not be touched between, but the axis should be carefully levelled.

13. If the meridian mark mentioned in (11) is well guarded, so that it is certain that it has never been moved, and is distinctly seen, the transit should by the azimuth screws be always brought upon it; but if there is any doubt upon this point, the transit should not be moved, but the position of the mark right or left, and its distance by estimation (in thicknesses of the wires) should be noted very frequently. In any case, this is the safe way when the error is small.

14. As a general rule in observing, level before and after every observation, if the time permits; observe circumpolar stars as often as possible,—one to every clock star, if possible.

(II.) *To determine the latitude by the transit.*

1. Suppose that the transit instrument has been adjusted to the meridian, and that the error of the chronometer has been obtained as has been described in instructions (1), it will be desirable to leave the pedestal of the transit for its proper transit observations undisturbed, and to take a new position for the new observations in the meridian line passing through the old position, which will be easily traced by means of the meridian mark.

2. Plant a common theodolite in the new position, observe the meridian mark, and then turn the telescope 90°, and thus fix on a mark as E. or W. mark. An azimuth compass will probably suffice, if there is no theodolite at hand (for extreme accuracy is not required, and observations to be made in the manner hereafter described will give the means of correcting the results); but trouble will be saved by fixing the azimuth as precisely as possible.

3. Plant the transit instrument on the site of the theodolite, and adjust it to the new E. or W. mark, and level it very carefully.

4. Prepare a list of stars whose declination is less than the latitude of the place, but by as small a quantity as possible. There are few stars in the Nautical Almanac

in this predicament, and you may be compelled to use other Catalogue stars. Compute roughly the zenith distance at which they will pass the prime vertical by the formula

$$\cos.\ Z\ D = \frac{\sin.\ \text{declination}}{\sin.\ \text{latitude}},$$

and the hour-angle at which they will pass the prime vertical by the formula

$$\cos.\ \text{hour-angle} = \frac{\tan.\ \text{declination}}{\tan.\ \text{latitude}}.$$

By means of these the time and position will be sufficiently well known. But if the latitude is very uncertain, it will be necessary to look out some minutes before the time computed.

5. The observation then will consist in simply noting the chronometer time at which the star passes the wires (taking the mean as usual): as the course of the star will be very oblique, it will be necessary to move the transit so that the star shall cross each wire at that part at which transits are usually observed.

6. This observation must be made when the star crosses the prime vertical both east and west of the meridian.

7. The observation being made, and corrected for chronometer error and rate, the mean time between the time at the east and the time at the west transit will be nearly (but perhaps not exactly) the same as the R. A. of the star. If it is greater than the R. A., it shews that the supposed E. mark was too far south, if the latitude of the station is north; or too far north, if the latitude of the station is south. This difference ought to be the same from different stars: convert it into arc. Then the error of azimuth of the mark will be found by the formula

$$\tan.\ \text{error of azimuth} = \tan.\ \text{converted difference} \times \text{by the } \sin.\ \text{latitude}.$$

By this formula the place of the mark can be altered, if it is thought necessary.

8. Half the difference between the east transit and the west transit is the star's observed hour-angle at passing the prime vertical. Then the latitude is determined at once by this formula:

$$\tan.\ \text{lat.} = \frac{\tan.\ \text{star's declination}}{\cos.\ \text{observed hour-angle}}.$$

This ought to result the same from different stars.

9. The latitude, or mean of all these latitudes, is to be corrected by the formula

$$\tan.\ \text{true diff.} = \tan.\ \text{approx. latitude} \times \cos.\ \text{converted difference}.$$

It will be scarcely altered by this computation, except the error of the mark be very considerable.

10. If these operations are continued for several nights, it will be proper to use the transit alternately illuminated end east and west, and not to meddle with the collimation error or adjustment.

11. The most scrupulous attention must be given to the levelling.

(III.) *To determine the latitude with the altitude and azimuth instrument.*

1. Adjust the axis *nearly* to verticality, and the cross axis *nearly* to horizontality. Accurate adjustment is not at all necessary.

2. Direct the telescope to the star, and bisect the star upon the middle horizontal wire, and note the time of the observation. Theoretically speaking, the star may be observed in any part of its course; but practically, any star, except the three circumpolar stars, should be observed within a few minutes of the time of its passing the meridian.

3. Read the large divisions with the pointer, and read the two microscopes, A and B, and enter the readings in your book; and read the level, *right hand* and *left hand*, and enter them in the book by those names, and not by north and south.

4. Then turn the instrument 180° in azimuth round its vertical axis, and go through the same operation.

5. Revert to the first position, and make an observation; and return to the second position, and make an observation; and so often as you think fit.

6. Read the barometer and thermometer.

The observation is now complete.

7. Add together for the first operation,—

Reading of A.
Reading of B.
Equivalent for left-hand level.*
Subtract equivalent for right-hand level.
Divide the remainder by 2.
Apply the pointer reading.

This gives the uncorrected circle reading of A.

8. Do the same for second observations (noting, however, that in the present state of divisions it will be sometimes necessary to increase one value by 90°), and you will have the uncorrected circle reading of second observation.

These are necessary in *all* observations.

9. The form of the further reduction will depend on the nature of the observation. Suppose, as a first case, that a star far from the pole has been observed near the meridian,—

10. For each observation correct the chronometer time from chronometer error, which will give the true sidereal time of observation, and take the difference between the sidereal time and the star's R. A., which will give the star's hour-angle. Reduce this to seconds. Suppose the number of seconds of time to be p,

11. Then compute for each observation the number

$$\left(\frac{225}{2}\sin. 1''\right) \times \frac{\text{cos. lat. . cos. star's declin}^{\text{n}}.}{\text{sin. star's Z D}} \times p^2,$$

and this is the correction in seconds of arc to the observed zenith distance, to bring it to the meridian zenith distance,—always subtractive, except the star is below the pole.

12. This correction is to be applied to the circle reading; and it will be sometimes additive, sometimes subtractive, according as increasing readings of the circle in that position shew increasing or decreasing zenith distances. For this purpose you must examine the construction of the circle. Thus the corrected circle readings for the meridian are found.

13. Half the difference of the two corrected circle readings in opposite positions of the instrument is the star's apparent zenith distance on the meridian. In using several pairs of observations, you may either compare the mean of all in one position with the mean of all in the other position, or follow any other rule usually adopted in similar cases. Half the sum of the corrected readings is the zenith point.

14. The refraction is to be computed and added to this approximate zen. dist., and it gives the star's true zenith distance.

* It is supposed here that when the observation on the star is made with the level to the observer's right hand, the increasing divisions read on the circle correspond to increasing zenith distances; if not, add equivalent for right-hand level, and subtract that for left.

15. Take out of the Nautical Almanac the star's declination for the day, considering it negative if the declination is of opposite name to that of the station. Add the true zenith distance, if the star is on the side of the zenith opposite to the pole, or add the true zenith distance to the star's declination, and subtract the sum from 180°, if the star is below the pole. Thus the latitude is obtained.

16. If the star is very far from the meridian, find the star's hour-angle (as in 10), and reduce it to arc. If this arc exceeds 90°, subtract it from 180°.

17. Find the star's distance from the meridian by the formula

$$\text{sin. dist. from meridian} = \text{cos. declin}^{\text{n}}. \times \text{sin. hour-angle.}$$

18. Find the star's distance above or below the pole by the formula

$$\text{tan. dist. above or below} = \text{cotan. declin}^{\text{n}}. \times \text{cos. hour-angle;}$$

(above, if the hour angle is less than 90°.)

19. From the circle reading (7, 8) and the approx. zenith point (13) obtain an approximate zenith distance to *seconds*, and correct for refraction.

20. Then compute

$$\text{cos. star's referred zenith distance} = \frac{\text{cos. approx. zenith distance}}{\text{cos. star's dist. from meridian}},$$

and add to the referred zenith distance the distance above or below the pole (18) if the hour-angle is less than 90°, and subtract if greater than 90°. Thus the co-latitude is found.

21. Do the same from the observation with the instrument in the opposite position, using exactly the same approximate zenith point.

22. The mean of the two is a good co-latitude.

(IV.) *To determine the sidereal time in a place whose latitude is known, by observation with the altitude and azimuth instrument.*

1. Select a Nautical Almanac star which at the time is nearly east or west, and not very low.

2. Observe it with the instrument in the same manner as for latitude, noting the chronometer time of observation, position of face, readings of microscopes, and readings of level.

3. Reverse instrument in azimuth and observe in like manner, noting the chronometer time. Repeat these observations if you think fit. Read barometer and thermometer.

4. Half the difference of the readings (fully reduced for microscopes and equivalent for levels) may be taken as the apparent zenith distance, corresponding to the mean of the times of observation.

5. Correct this apparent zenith distance for refraction, and you have the true zenith distance.

6. Take the star's declination from the Nautical Almanac, and subtract from 90°, if the declination is of the same name as the latitude, or add if of opposite name, which gives the polar distance: in like manner find co-latitude from latitude.

7. Add together true zenith distance, star's polar distance, and co-latitude, and call the sum S.

Formula, S − star's N P D, and S − co-latitude.

8. Then compute the hour-angle by the following formula:

$$\begin{aligned} 2 \text{ log. sin. } \tfrac{1}{2}\text{-hour angle} &= \text{log. sin. (S} - \text{star's N P D)} \\ &+ \text{log. sin. (S} - \text{co-latitude)} + 20 - \text{log. sin. star's N P D} \\ &- \text{log. sin. co-latitude.} \end{aligned}$$

Convert the hour-angle into time.

9. If the star is west of the meridian, add this hour-angle to the star's R. A. (taken from the Nautical Almanac), and you have the true sidereal time. If the star is east, subtract the hour-angle from the star's R. A.

10. The difference of the mean of the two chronometer times from this sidereal time is the error of the chronometer.

(v.) *To determine the latitude and the sidereal time in a place where neither of them is known, by observations with the altitude and azimuth instrument.*

1. For this purpose two Nautical Almanac stars must be selected, and it is *indispensable* that *both* be *not* east or west: one may be nearly east or west; but the other must be nearly north or south. But as this choice might lead to a little trouble in the following computations, I recommend that in all cases two stars in positions pretty near to the directions intermediate to the cardinal points be taken,—thus:

One nearly	N. E.,	and the other nearly	S. E., or
„	S. E.,	„	S. W., or
„	S. W.,	„	N. W., or
„	N. W.,	„	N. E.

It is indispensable that the azimuth be not nearly opposite, or the same; their difference ought to be as nearly as possible 90°.

2. Observe one star; note the time exactly; read the microscopes and level, and do the same as in IV. (2 & 3.)

3. Observe the other star in exactly the same manner. Read barometer and thermometer.

4. Find the apparent zenith distance, and correct for refraction to obtain true zenith distance as in other cases.

5. From a map, (or from any other means,) estimate your latitude as well as you can, and then take two trial latitudes, one somewhat less and the other somewhat greater than the estimated latitude. As your uncertainty will never exceed a few minutes, it will probably suffice to take one trial latitude 5′ greater and one 5′ less than the estimate.

6. With each trial latitude, determine the chronometer error (IV. 10) by each of the stars, going through the operation of No. IV. four times.

7. The true altitude will be that which makes its two chronometer errors equal. Probably neither of the trial latitudes will do this. But observing how much the discordance alters between them, you will have no difficulty in finding the true latitude which will remove the discordance. Thus—suppose latitude 45° 15′ made the chronometer error by star A. $46^s{\cdot}2$, and by star B. $50^s{\cdot}2$ (discordant 4 seconds); and suppose latitude 45° 25′ made the error by A. $53^s{\cdot}4$, and by B. $37^s{\cdot}4$ (discordant 16^s the opposite way); then 10′ of latitude has changed the discordance 20^s, and therefore 2′ of latitude will remove the first discordance of 4^s, and the latitude is 45° 17′; and since 10′ altered the error by A. $7^s{\cdot}2$, and by B. $12^s{\cdot}8$, 2′ will alter the former by $1^s{\cdot}44$, and the latter by $2^s{\cdot}56$; and both agree in giving the error $47^s{\cdot}64$.

(VI.) *Observations of equal altitude not recommended for use.*

1. If the object of these observations is simply to obtain the correction of the chronometer, the observations should be taken as near as possible to the prime vertical, east or west.

2. For a star, the instrument, whatever it is, should be set to a known reading, and the time should be noted when the star reaches that reading in the east; again

the star should be noted when it reaches the same reading in the west. The mean of these two times is the same when the star passes the meridian.

3. It will be best not to keep the instrument fixed, but to set it successively to a number of different readings on the east side, and to set it again to the same readings in the opposite direction. Thus a number of different results will be obtained, and the risk of loss will be diminished.

4. For the sun, the same limb (upper or lower) should be observed; but there is an additional correction necessary for the change of the sun's declination, or N. P. D. If the N. P. D. is *increasing*, the sun reaches the same Z. D. on the west side *too soon*, and therefore the time for the west side must be increased. The calculations will be thus: the increase of the sun's N. P. D. will be calculated (the interval of time being nearly known) from the Nautical Almanac: the latitude of the station is supposed to be nearly known, and the approximate hour-angle at either observation (half the interval of time converted into arc) is nearly known. Then the correction to western time in seconds of time is—

$$\frac{\text{tan. latitude}}{15\,.\,\text{sin. hour-angle}} \times \text{increase NPD} - \frac{\text{tan. declin}^{\text{n}}.}{15\,.\,\text{tan. hour} <} \times \text{increase NPD};$$

the increase of N. P. D. being taken as seconds of arc.

Then the means are to be taken as for a star.

5. If the object is to obtain latitude as well as chronometer correction, the two sets of observations should be made when the star or sun is nearly S. E. or S. W. The method of making the observations, and applying corrections to the time, and thence deducing the time of transit, is the same as before.

6. Then the accurate hour-angle for the first observation (the difference between the time of observation and the time of transit) being found, and the absolute zenith distance being taken and corrected for refraction, and in the instance of the sun for parallax and semi-diameter, and the star's or sun's N. P. D. being taken accurately from the Nautical Almanac, the latitude will be found by the following process:

$$\left.\begin{array}{r}\text{Tan. star's referred}\\ \text{dist. from pole}\end{array}\right\} = \text{tan. NPD} \times \text{cos. hour-angle.}$$

$$\text{Sin. star's azimuth} = \frac{\text{sin. hour} < \times \text{ sin. NPD}}{\text{sin. zenith distance}}.$$

$$\left.\begin{array}{r}\text{Tan. star's referred}\\ \text{dist. from zenith}\end{array}\right\} = \text{tan. zenith dist.} \times \text{cos. azimuth.}$$

Co-lat. = star's referred distance from pole − star's referred distance from zenith.

(VII.) *General remarks on the rise of the sun instead of a star, in any of the preceding observations.*

1. The sun may be substituted for a star in any of the various classes of observations already mentioned. But its use is always more troublesome, and it comes, for many of them, but once a day; and for some it is useless, if it can be caught but once in a hasty sight. It is recommended, therefore, that the principal, if not the only reliance, be placed on observations of stars.

2. In using the sun, the time by account must always be reduced to Greenwich mean time, and with this the sun's place must be computed from the Nautical Almanac. Thus, in longitude 67° 50′ west (by account), suppose that the sun was observed on May the 24th, about three in the afternoon (by the reputed time at the place); then as the sun passes Greenwich before he passes this western place, the time will be later at Greenwich by the time corresponding to 67° 50′ of arc, or 4 h. 31 m. 20 s.: therefore the time at Greenwich will be, May 24th, 7 h. 31 m. nearly; and with this

time the sun's R. A. and N. P. D. must be computed, by interpolation, among the places given in the Nautical Almanac for Greenwich mean noon.

3. The change of the sun's N. P. D. must, in many instances, be taken into account. Thus, if the sun were observed as in No. II., the change of N. P. D. between the first observation and the second must be computed, and it must be considered that if the N. P. D. is increasing, the second observation occurs too late, and must be corrected by the quantities

$$-\frac{1}{15 \,.\, \text{sin. NPD} \times \text{cos. NPD} \,.\, \text{tan. hour-angle}} \times \text{change of NPD};$$

the change of N. P. D. being expressed in seconds of arc, and the correction to time being expressed in seconds of time. Then, in further operations, the N. P. D. for the first observation must be used.

A similar result of change of N. P. D. is given in No. VI.

4. In all cases where the sun's altitude or zenith distance is measured, parallax must be applied subtractively from observed zenith distances.

Its formula is $8''\cdot 7 \times$ sin. zenith distance. It is to be used in Nos. III. IV. V.

5. In all cases observations must be made of the sun's limb, and not of his centre, which cannot be fixed on with accuracy. If possible, therefore, observations should be so managed that the observations of the two limbs should prevent the necessity for applying any correction for semi-diameter. Thus, in transits the first and second limb should be observed. In altitudes (whether for latitude or time), the upper and lower limbs should be observed. If from clouds, &c., this cannot be done,—for transits, the duration of transit of semi-diameter, from the Nautical Almanac, must be applied. For altitudes, the semi-diameter, taken from the Nautical Almanac, must be applied, after application of refraction and parallax. Observations on the stars are free from all these troubles.

(Signed) G. B. AIREY.

PART III.—OBSERVATORY, PORTABLE.*

According to the nature and size of the instrument to be protected, Portable Observatories are made either of wood, or partly of wood and partly of canvas, strengthened with iron ties and iron angle-bars, and secured in position by guy-ropes, pickets, &c. On the Ordnance Survey of Great Britain, four kinds or classes are used for the various sized theodolites which are employed on the triangulation.

Plates VIII. and IX.

Fig. No. 1 is for the largest class of theodolite used, viz. the 3-feet. Its form is hexagonal, and it consists of the following pieces:

1. Six panels of wood, each 5 feet 6 inches long by 4 feet 6 inches high, framed of 1-inch deal with ½-inch boarding. (See fig. 4.)

The top style carries two pieces of flat iron, with eyes to receive corner-iron bars: one of the under cross-bars also carries two eyes, to receive the lower angle-bars.

2. Six corner-posts of deal (fig. 5), to support the roof, each 4 feet 6 inches high, 3 inches in diameter.

The top has a hole sunk in it, 3 inches in depth, to receive the upright angle-bar, and is bound round with iron plate to strengthen it at this part.

3. Six iron corner bars (fig. 6), made double in the centre, with an opening 3 inches wide. The lower end goes into the top of the corner post; the upper end receives the wall-plates, rafter, and rose for guy-rope: they are made of rod iron, 1 inch in diameter. They revolve, and admit of objects being observed through them.

* By Major Robinson, R. E.

Plate IX. 4. Six wall-plates of deal, 5 feet 6 inches long, 2 inches wide by 2 inches deep. (Fig. 3.) These are notched, and bound with sheet iron at the ends, and have a hole bored through, to fit upon the iron angle-bars.

5. Six rafters, 7 feet long, 2½ inches wide by 2 inches deep; the lower end bevelled, and shod with sheet iron, and bored, to go upon the angle-bar. These are all fastened with but-hinges to one central piece of wood of 1 foot in diameter by 2 inches thick: when taken down, the rafters close together, and are carried in a long canvas bag.

6. One iron bolt (fig. 3), 12 inches long, 1¼ inch diameter, passes through this central block: it has a screw and nut on the under side, and a shoulder on the outside: it is to receive the large rose which carries the long guy-ropes.

Plate VIII. 7. Six iron bars (fig. 1), 4 feet long, 1 inch diameter, and six of 3 feet long, 1 inch diameter, to bind the panels together at the angles. The upright posts are secured in their places and to the panels by twelve iron angle-pieces and twelve iron shackles Plate IX. (figs. 7 and 8). The former are of ⅜-inch flat iron, bent to an angle of 120°, with projecting pieces passing through the panels, having holes to receive the ends of the shackles.

The roof is covered with a very strong description of sail canvas, of double thickness: the seams are strengthened with girth webbing. It is made in one piece, and is put on from the outside, sliding down over the rafters, and has eyelet-holes, to receive the projecting ends of the iron angle-bars.

Attached to this roof are curtains made of the same canvas (but only once thick), of 2 feet in depth, which cover the openings between the top of the panels and the wall-plates. The lower ends button over iron staples provided in the panels, and are secured by cords passing through them.

The curtains are rolled up when required, and tied to the wall-plates. Each panel has a piece of painted canvas, fixed at one side, of about 7 or 8 inches wide, which buttons over the angle upon a row of iron staples in the next panel.

Two panels, each provided with a small door, 1 ft. 8 in. wide by 2 ft. 8 in. deep, are usually placed north and south.

For the purpose of observing the Pole star, by which the direction of the meridian is obtained, a piece is cut out of the canvas roof, on the north side, leaving an opening Plate VIII. of 3 feet long by 1 foot wide (fig. 2). To cover this, when not required for observing, this side has an extra thickness or flap of canvas, which is sewn at one side, and buttons over a row of iron staples, fastened to the canvas of the opposite angle, and secured by a bit of cord run through them.

A large wooden rose fits upon the iron bar projecting through the roof at top, and six long guy-ropes, of about 100 feet each in length, are attached to it, to be secured to pickets in the ground. A smaller rose fits upon each projecting end of the angle-bars, and has a small guy-rope attached to it.

For use, the observatory inside is generally floored with joists and boards, leaving n the centre a well for the pedestal or frame-work supporting the instrument, care being taken that the latter is perfectly insulated, so as to be free from shake or jar, from persons walking on the floor.

This kind of observatory is used upon the highest mountains and in the most exposed places. It is generally the practice, however, to build round it on the outside, and just touching it, a wall of loose stones, about half-way up the panels. With this precaution, it was never known (for years) to yield or give way in the least, although, at times, every thing else in the camp would be blown over and levelled with the ground.

Plate IX. figs. 3, 4, 5, 6, 7, 8. No. 2.—This class of observatory is used for the second class of theodolites, such

as the 18-inch. It is precisely similar in its construction to the former, but is a size smaller, each panel being made about 4 feet 9 inches in length by 4 feet in height. The dimensions of the other parts are lessened to correspond with the panels. This observatory is also very strong, and may be used in the most exposed situations.

Plate X. No. 3.—This is used in the District Surveys for the 12-inch or 10-inch theodolites: the shape, like the former ones, is hexagonal. It consists of a canvas roof, with side curtains, also of canvas, reaching to the ground, supported upon a skeleton frame-work, consisting of

Six upright poles, 5 feet 9 inches long, 2¼ inches diameter, with projecting iron pins, 8 inches long, at the upper end, to receive the wall-plates and rafters: the tops are bound with a piece of sheet iron.

Six wall-plates, each 4 feet long, 1¾ inch by 1¾ inch, with holes at the ends, to pass over the pins upon the top of the upright poles.

Six rafters, 5 feet 3 inches long, 2 inches by 1¾ inch, all permanently fastened by but-hinges to a central piece of wood, 8 inches diameter and 2 inches thick.

An iron bolt, with moveable nut underneath, passes through this, to receive the rose on the top.

The canvas roof goes over the frame-work, and is made in one piece, with flaps 8 inches deep.

The canvas walls are made separate from the roof, in one or two pieces, and are fastened to it with hooks and eyes. For use, they are unhooked, and drawn on one side.

Plate XI. fig. 11. No. 4 is used in the District Surveys for the smaller theodolites, 7-inch, &c.

A triangular frame of wood, each side 3 feet in length, is supported upon three poles or legs, each 7 feet 4 inches long: the canvas covering consists of two pieces: 1st, The head, which covers the triangle at the top, and extends about 2 feet down the sides of the poles: it is made of strong duck canvas. 2ndly, The walls are made of a piece of duck canvas, 15 feet 6 inches long at the bottom, 9 feet 6 inches at the top, and 5 feet 4 inches wide.

This covers in two sides of the triangle only, but it can be shifted to any two required for shelter from the wind. The canvas walls button over iron staples in the poles supporting the head. The side walls to the latter can be raised when required, by a piece of wood notched at the foot and resting upon the corner guy-rope. The upright poles have an iron pin at the foot, 3 inches long, and at the top there is an iron prong, or fork of flat iron, by which they are secured to the top pieces by nuts and screws.

The Portable Observatory for the zenith sector, shewn in Plates XII. and XIII., is a wooden building formed of panels and uprights, which can be strongly bound together: the side panels are fitted into rabbets cut in the frame, and secured on the inside with bent iron plates and screws. It is 10 feet square in plan at the bottom, and 8 feet 10 inches square at the top; 10 feet in height to spring of roof; rise of roof, 2 feet.

The four corner posts are of $5'' \times 5''$ scantling,—the four bottom plates are of $6'' \times 5''$ ditto,—bolted and nutted to the corner posts as in a bedstead;—the four top plates are of $5'' \times 5''$ scantling, notched and pinned to the corner posts.

The frame is strengthened mid-way by four additional horizontal pieces.

Each side has three upright pieces, $3'' \times 3''$, mortised and tenoned into the plates.

There are eight panels to each side, of ½-inch boarding.

On the north and south sides one of the panels is hung as a door, and contains a small glass window.

The roof has an opening in the centre of 5 feet 4 inches long by 1 foot 4 inches

wide, fitted with two small trap-doors, which are opened or shut from the inside by means of a cord passing through a fixed pulley at the end of an iron rod, as shewn in the section, and carried through another fixed pulley in one of the side posts.

The roof is formed of six panels which slide in grooves in the sides of the hip and central rafters.

The corner posts and wall-plates have iron staples driven into them.

The whole building is covered with duck canvas, which buttons over these staples, and cords run through them keep all secure.

The floor is formed of joists and boards, leaving room for the pedestal or frame-work support for the instrument in the centre.

This observatory may be used in the most exposed situations.

Plate XIV. shews a Portable Observatory which was made for a Transit instrument, and used at Valentia, in Ireland. It is a wooden building, strongly framed together. The sides and ends are formed of panels fitted into rabbets cut in the scantling of the frame-work, and secured to them on the inside with bent iron plates and screws.

In plan, the building is 10 feet 9 inches by 8 feet 5 inches; the height is 7 feet 10 inches to spring of roof; rise of the latter, 4 feet.

There are two tie-beams, king-posts, and rafters in the centre, leaving between them an opening of 1 foot 1 inch in the clear on the sides of the roof. This opening is continued to the ground-plate on each side.

Doors are fitted to these openings, which can be raised or shut at pleasure from the inside. The door in the roof is raised by means of a cord attached to one end of a small iron lever, turning on a pivot, secured to one of the rafters, and having a small roller wheel at the other end.

The roof is formed of eight angular panels, which slide in grooves cut in the sides of the rafters.

Iron staples are fixed in the corner posts and wall-plates, over which a covering of canvas duck is buttoned and secured by cords passing through them.

Stars near the zenith are observed by turning the double iron bar which forms the ridge of the roof between the two king-posts.

A similar bar is provided in the top wall-plates, which might otherwise interfere with the observations.

The Officers employed on the Boundary Survey in North America, under the Treaty of Washington, used tents for observatories, made of duck canvas only, supported upon a ridge-pole 10 feet long, with two upright poles of 10 feet each.

In plan, the tent enclosed a space of 10 feet square.

The north and south sides had canvas walls, 5 feet high.

In the slope of the roof, on each side, a portion of the canvas was made to turn back, leaving an opening, when required for observing, of about 1 foot 6 inches wide.

When the ridge-pole interfered with a star passing near the zenith, it was lowered a little by slackening the guy-ropes.

These were for the protection of the transit instruments. The altitude and azimuth instruments were used always in the open air, without any observatory.

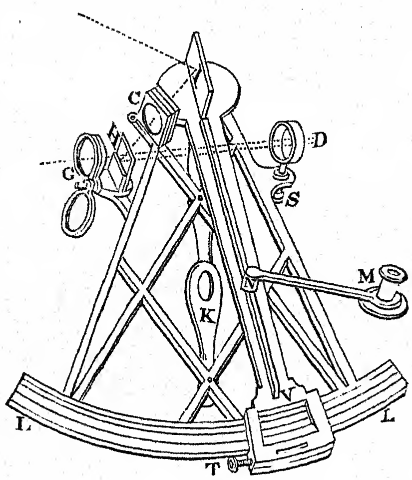
W. R.

PART IV. — DESCRIPTION OF THE PRINCIPAL ASTRONOMICAL INSTRUMENTS.*

1. Hadley's Sextant; 2. Troughton's Reflecting Circle; 3. The Transit Instrument; 4. Altitude and Azimuth Instruments; with brief remarks upon other instruments used for astronomical purposes.

Hadley's Sextant. — This instrument differs from the pocket sextant in its appearance, from the absence of the box in which the pocket sextant is fixed, and in its size, varying usually from 4 inches to 6 inches radius, and in its requiring and admitting of more perfect and minute adjustment.

L L is the graduated limb of the instrument, graduated from 0° to 140° at every 10′ or 20′, according to its size, and subdivided by the vernier V, to 10″ or 20″, thus enabling us to read off angles by estimation, to 5″. The limb is also graduated through a small space, called the arc of excess, on the other side of the zero point. T is the tangent screw, for giving a slow motion to the index bar, after it has been clamped by a screw at the back of the instrument, not shewn in the figure. M is a microscope, attached to the index bar by an arm moveable round the centre N, so as to command a view of the vernier throughout its entire length. I is the index glass, or first reflector, attached to and moving with the index bar; and H is the horizon glass, having its lower half silvered to form the second reflector, and its upper half transparent. Four dark glasses are placed at C, any one or more of which can be turned down between the index glass and horizon glass to moderate the intensity of the light from any very bright object viewed by reflection; and at G are three dark glasses, any one or more of which can be turned up to moderate the intensity of the light from any bright object viewed directly through the transparent part of the horizon glass. D is a ring



for carrying the telescope, attached to a stem S, called the up-and-down piece, which can be raised or lowered by means of a milled-headed screw. The use of this up-and-down piece is to raise or lower the telescope, till the objects seen directly and by reflection appear of the same brightness. K is the handle by which the instrument is held.

In selecting an instrument, care must be taken that all the joints of the frame are close, without the least opening or looseness, and that all the screws act well, and remain steady, while the instrument is shaken by being carried from place to place. All the divisions on the limb and vernier, when viewed through the microscope, must appear exceedingly fine and distinct, and the inlaid plates, upon which the divisions

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are marked, must be perfectly level with the surface of the instrument. The index, or zero, of the vernier, should also be brought into exact coincidence successively with each division of the limb, till the last division upon the vernier reaches the last division upon the limb; and if the last division of the vernier do not in each case also exactly coincide with a division upon the limb, the instrument is badly graduated, and must be rejected. All the glass used in the instrument should be of the best quality, and the glasses of the reflectors should each have their faces ground and polished perfectly parallel to each other, to avoid refraction. Look, therefore, into each reflector, separately, in a very oblique direction, and observe the image of some distant object; and if the image appears clear and distinct in every part of the reflector, the glass is of good quality; but if the image appears notched, or drawn with small lines, the glass is veiny, and must be rejected. Again, if the image appears singly, and well defined about the edges, the two surfaces of the glass are truly parallel; but if the edge of the image appears misty, or separated like two images, the two surfaces are inclined to one another. The examination will be more perfect if the image be examined with a small telescope.

A plain tube and two telescopes, one shewing objects inverted, and the other erect, are usually supplied with the sextant. A dark glass is also supplied to fit on to the eye-end of the telescope, and a key for turning the adjusting screws.

To examine the error arising from the imperfection of the dark glasses.—Fit the dark glass to the eye-end of the telescope, and, all the shades being removed, bring the reflected image of the sun into contact with his image seen directly through the unsilvered part of the horizon glass. Then remove the dark glass from the eye-end of the telescope, and, setting up first each shade separately, and then their various combinations, if the two images do not in any case remain in contact, the angle through which the index must be moved to restore the contact is the error of the dark glass, or combination of dark glasses, used in the observation, and which error should be recorded for each glass and each combination of the glasses.

The adjustments of the instrument consist in setting the horizon glass perpendicular to the plane of the instrument, and in setting the line of collimation of the telescope parallel to the plane of the instrument.

To adjust the horizon glass.—While looking steadily at any convenient object, sweep the index slowly along the limb, and if the reflected image do not pass exactly over the direct image, but one projects laterally beyond the other, then the reflectors are not both perpendicular to the face of the limb. Now the index glass is fixed in its place by the maker, and generally remains perpendicular to the plane of the instrument, and if it be correctly so, the horizon glass is adjusted by turning a small screw at the bottom of the frame in which it is set, till the reflected image passes exactly over the direct image.

To examine if the index glass be perpendicular to the plane of the instrument.—Bring the vernier to indicate about 45°, and look obliquely into this mirror, so as to view the sharp edge of the limb of the instrument by direct vision to the right hand, and by reflection to the left. If, then, the edge and its image appear as one continued arc of a circle, the index glass is correctly perpendicular to the plane of the instrument; but if the arc appears broken, the instrument must be sent to the maker to have the index glass adjusted.

To adjust the line of collimation.—1. Fix the telescope in its place and turn the eye-tube round, that the wires in the focus of the eye-glass may be parallel to the plane of the instrument. 2. Move the index till two objects, as the sun and moon, or the moon and a star, more than 90° distant from each other, are brought into contact at the wire of the diaphragm which is nearest the plane of the instrument.

3. Now fix the index, and altering slightly the position of the instrument, bring the objects to appear on the other wire; and if the contact still remain perfect, the line of collimation is in correct adjustment. If, however, the two objects appear to separate at the wire that is further from the plane of the instrument, the object-end of the telescope inclines towards the plane of the instrument; but, if they overlap, then the object-end of the telescope declines from the plane of the instrument. In either case the correct adjustment is to be obtained by means of the two screws which fasten to the up-and-down piece the collar holding the telescope, tightening one screw and turning back the other, till, after a few trials, the contact remains perfect at both wires.

The instrument having been found by the preceding methods to be in perfect adjustment, set the index to zero, and if the direct and reflected images of any object do not perfectly coincide, the arc, through which the index has to be moved to bring them into perfect coincidence, constitutes what is called the index error, which must be applied to all observed angles as a constant correction.

To determine the index error.—The most approved method is to measure the sun's diameter, both on the arc of the instrument, properly so called, to the left of the zero of the limb, and on the arc of excess to the right of the zero of the limb. For this purpose, firstly, clamp the index at about 30′ to the left of zero, and, looking at the sun, bring the reflected image of his upper limb into contact with the direct image of his lower limb, by turning the tangent screw, and set down the minutes and seconds denoted by the vernier: secondly, clamp the index at about 30′ to the right of zero, on the arc of excess, and, looking at the sun, bring the reflected image of his lower limb into contact with the direct image of his upper limb, by turning the tangent screw, and set down the minutes and seconds denoted by the vernier underneath the reading before set down. Then half the sum of these two readings will be the correct diameter of the sun, and *half their difference will be the index error.* When the reading on the arc of excess is the greater of the two, the index error, thus found, must be added to all the readings of the instrument; and when the reading on the arc of excess is the less, the index error must be subtracted in all cases. To obtain the index error with the greatest accuracy, it is best to repeat the above operation several times, obtaining several readings on the arc of the instrument, and the same number on the arc of excess; and the difference of the sums of the readings in the two cases, divided by the whole number of readings, will be the index error; while the sum of all the readings, divided by their number, will be the sun's diameter.

EXAMPLE.

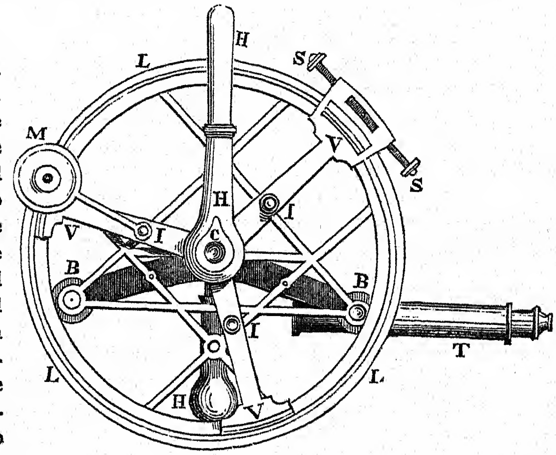
	Readings on the Arc of Instrument.			Readings on the Arc of Excess.		
	′	″		′	″	
	35			29	25	
	35	5		29	35	
	35	10		29	20	
	105	15		88	20	
	88	20		105	15	
No. of readings	6) 16	55	difference.	6) 193	35	sum.
	2	49	index error.	32	15·8	sun's diameter.

The readings on the arc of excess being less than those on the arc of the instru-

ment, the index error, 2′ 49″, is to be subtracted from all the readings of the instrument.

Note.—In taking off the readings on the arc of excess, the vernier must be read backwards; that is, the division read off on the limb, being the division next to the left of the zero of the vernier, the divisions of the vernier to be added must be reckoned from the other end of the vernier to the division coinciding with a division upon the limb; or the reading of the vernier forwards, according to the usual method, may be subtracted from 10′, the limb being divided to 10′, and the remainder added to the reading of the division upon the limb next to the left of the zero of the vernier, as before.

Troughton's Reflecting Circle.—In this instrument, which is the same in principle as the sextant, the limb is a complete circle, L L L. It has three verniers, V V V, one of which is furnished with the clamp and tangent screw, S S, for regulating the contacts; and the verniers are read by a magnifier, M, which may be applied successively to all the verniers. In the middle of the frame, and attached to it by a broad base or flanch, is a hollow centre, upwards of 2 inches long, in which an axis revolves. The triple vernier bar, I I I, is attached at one end of the axis, and the index glass at the other, so that both turn together, but on opposite sides of the instrument. A secondary frame, B B, carries the telescope T, the horizon glass, and the dark glasses. H H are two handles, one of them bent, and passing round to the centre of the instrument on the other side; and there is a third handle, which can be screwed on perpendicular to the plane of the instrument, either into the handle at C, or upon the other side of the instrument, at its centre. The adjustments and manner of observing with the instrument are explained by the inventor, Mr. Troughton, as follows:



Directions for observing with Troughton's reflecting circle.—"Prepare the instrument for observation by screwing the telescope into its place, adjusting the drawer to focus, and the wires parallel to the plane, exactly as you do with a sextant: also set the index forwards to the rough distance of the sun and moon, or moon and star; and, holding the circle by the short handle, direct the telescope to the fainter object, and make the contact in the usual way. Now read off the degree, minute, and second, by that branch of the index to which the tangent screw is attached; also, the minute and second shewn by the other two branches: these give the distance taken on three different sextants; but as yet, it is only to be considered as half an observation: what remains to be done, is to complete the whole circle, by measuring that angle on the other three sextants. Therefore set the index backwards nearly to

the same distance, and reverse the plane of the instrument, by holding it by the opposite handle, and make the contact as above, and read off as before what is shewn on the three several branches of the index. The mean of all six is the true apparent distance, corresponding to the mean of the two times at which the observations were made.

"When the objects are seen very distinctly, so that no doubt whatever remains about the contact in both sights being perfect, the above may safely be relied on as a complete set; but if, from the haziness of the air, too much motion, or any other causes, the observations have been rendered doubtful, it will be advisable to make more: and if, at such times, so many readings should be deemed troublesome, six observations, and six readings, may be conducted in the manner following:—Take three successive sights forwards, exactly as is done with a sextant; only take care to read them off on different branches of the index. Also make three observations backwards, using the same caution: a mean of these will be the distance required. When the number of sights taken forwards and backwards are unequal, a mean between the means of those taken backwards and those taken forwards will be the true angle.

"It need hardly be mentioned, that the shades, or dark glasses, apply like those of a sextant, for making the object nearly of the same brightness; but it must be insisted on, that the telescope should, on every occasion, be raised or lowered, by its proper screw, for making them perfectly so."

The foregoing instructions for taking distances apply equally for taking altitudes by the sea or artificial horizon, they being no more than distances taken in a vertical plane. Meridian altitudes cannot, however, be taken both backwards and forwards the same day, because there is not time; all, therefore, that can be done is, to observe the altitude one way, and use the index error; but, even here, you have a mean of that altitude, and this error taken on three different sextants. Both at sea and land, where the observer is stationary, the meridian altitude should be observed forwards one day, and backwards the next, and so on alternately from day to day: the mean of latitudes, deduced severally from such observations, will be the true latitude; but in these there should be no application of index error, for that being constant, the result would in some measure be vitiated thereby.

"When both the reflected and direct images require to be darkened, as is the case when the sun's diameter is measured, and when his altitude is taken with an artificial horizon, the attached dark glasses ought not to be used: instead of them, those which apply to the eye-end of the telescope will answer much better; the former having their errors magnified by the power of the telescope, will, in proportion to this power, and those errors, be less distinct than the latter.

"In taking distances, when the position does not vary from the vertical above thirty or forty degrees, the handles which are attached to the circle are generally most conveniently used; but in those which incline more to the horizontal, that handle which screws into a cock on one side, and into the crooked handle on the other, will be found more applicable.

"When the crooked handle happens to be in the way of reading one of the branches of the index, it must be removed, for the time, by taking out the finger screw which fastens it to the body of the circle.

"If it should happen that two of the readings agree with each other very well, and the third differs from them, the discordant one must not on any account be omitted, but a fair mean must always be taken.

"It should be stated, that when the angle is about thirty degrees, neither the distance of the sun and moon, nor an altitude of the sun, with the sea horizon, can

be taken backwards; because the dark glasses at that angle prevent the reflected rays of light from falling on the index glass: whence it becomes necessary, when the angle to be taken is quite unknown, to observe forwards first, where the whole range is without interruption; whereas in that backwards you will lose sight of the reflected image about that angle. But in such distances, where the sun is out of the question, and when his altitude is taken with an artificial horizon, (the shade being applied to the end of the telescope,) that angle may be measured nearly as well as any other; for the rays incident on the index glass will pass through the transparent half of the horizon glass without much diminution of their brightness.

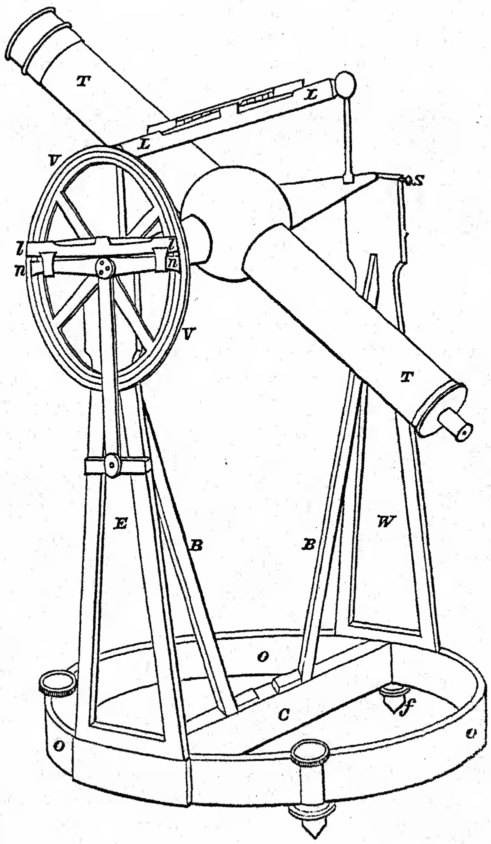
"The advantages of this instrument, when compared with the sextant, are chiefly these: the observations for finding the index error are rendered useless, all knowledge of that being put out of the question by observing both forwards and backwards. By the same means the errors of the dark glasses are also corrected; for if they increase the angle one way, they must diminish it the other way by the same quantity. This also perfectly corrects the errors of the horizon glass, and those of the index glass very nearly. But what is of still more consequence, the error of the centre is perfectly corrected by reading the three branches of the index; while this property, combined with that of observing both ways, probably reduces the errors of dividing to one-sixth part of their simple value. Moreover, angles may be measured as far as one hundred and fifty degrees, consequently the sun's double altitude may be observed when his distance from the zenith is not less than fifteen degrees, at which altitude the head of the observer begins to intercept the rays of light incident on the artificial horizon; and, of course, if a greater angle could be measured, it would be of no use in this respect.

"This instrument, in common with the sextant, requires three adjustments; first, the index glass perpendicular to the plane of the circle. This being done by the maker, and not liable to alter, has no direct means applied to the purpose; it is known to be right when, by looking into the index glass, you see that part of the limb which is next you, reflected in contact with the opposite side of the limb as one continued arc of a circle: on the contrary, when the arc appears broken where the reflected and direct parts of the limb meet, it is a proof that it wants to be rectified. The second is, to make the horizontal glass perpendicular. This is performed by a capstan screw, at the lower end of the frame of that glass; and is known to be right when by a sweep of the index the reflected image of any object will pass exactly over, or cover the image of that object seen directly. The third adjustment is, for making the line of collimation parallel to the plane of the circle. This is performed by two small screws, which also fasten the collar into which the telescope screws to the upright stem on which it is mounted: this is known to be right when the sun and moon, having a distance of one hundred and thirty degrees, or more, their limbs are brought in contact, just at the outside of that wire which is next to the circle, and then examining if it be just the same at the outside of the other wire: its being so is the proof of adjustment."

Another instrument of Troughton's construction upon the principle of the sextant is the *Dip Sector*, for measuring the dip of the horizon. Any person who is thoroughly acquainted with the sextant will find no difficulty in using it, after a few words of explanation from the maker.

The Transit Instrument.—The reflecting instruments, which we have just described, from their portability and the promptitude and facility with which they may be used in all situations, and upon all occasions, are most useful instruments to the surveyor. The sextant or reflecting circle, with an artificial horizon, and a good chronometer, forms, in fact, a complete observatory, with which the latitudes and

longitudes of places may be determined to a great degree of accuracy; while to the navigator a reflecting instrument is indispensable; all other instruments requiring to be supported upon a stand perfectly at rest, while the sextant and similar instruments are held in the hand, and perform their duty well on the deck of a rolling ship. In permanent observations, however, the capital angular instruments are placed permanently in the plane of the meridian, and the measurements sought for by their aid are the exact times at which the observed objects pass the meridian, and their angular altitudes or zenith distances when upon the meridian. The instrument with which the first of these measurements is obtained is called a *transit instrument, transit telescope*, or merely a *transit*. Transits of portable dimensions, besides their use in small or temporary observatories, are also found serviceable to the surveyor, for determining, with the greatest possible accuracy, the true north point, and thence setting out a line in any required direction; and to the scientific traveller, for determining the longitude of any place from astronomical observations, and for adjusting his time-keepers with greater accuracy than can be obtained by his sextant or reflecting circle. The annexed figure represents a portable transit.



T T is a telescope formed of two parts, connected by a spherical centre-piece, into which are fitted the larger ends of two cones, the common axis of which is placed at right angles to the axis of the telescope, to serve as the horizontal axis of the instrument. The two small ends of these cones are ground into two perfectly equal cylinders, called *pivots*. The pivots rest upon angular bearings or Y's. The Y's are supported upon the standards E and W, of which E may be called the eastern, and W the western standard; and one of the Y's is fixed in a horizontal groove, on the western standard, so that, by means of the screw S, one end of the axis may be pushed a little forwards or backwards, and a small motion in azimuth be thus communicated to the telescope.* The standards, the E and W, are

* The large transits in permanent observations have their Y's placed in two dove-tailed grooves, one horizontal, and the other vertical. By means of the latter, one end of the axis may be raised or

fixed by screws upon a brass circle, O O O, and steadied by oblique braces, B B, which spring from the cross-piece C.

On one end of the axis is fixed, so as to revolve with the axis, a vertical circle, V V; and a double index bar, furnished with a spirit-level, *l l*, to set it horizontal, carries two verniers, *n n*, adapted to the vertical circle, and shewing the angle of elevation of the telescope. The index bar is fixed in its position by a clamping screw, and can be fixed upon either the eastern or western standard, at pleasure, while the telescope, with its attached circle, can also be lifted out of, and have its position reversed in, the Y's. The pivot, which does not carry the vertical circle, is pierced, and allows the light from a lamp to fall upon a plane speculum, fixed, in the spherical centre piece, on the axis of the telescope, and inclined to this axis at an angle of 45°. The light is thus thrown directly down the telescope, and illuminates the wires of the diaphragm, placed in the principal focus of the telescope. Of these wires, one is horizontal; and a vertical wire, intersecting it in the centre of the field of view, gives, by its intersection with it, the collimating point. There are, then, other vertical wires arranged in pairs equidistant from the central vertical wires, so that we have either three, or five, or seven vertical wires, the most common number being five. The lamp has a contrivance for regulating the quantity of light thrown into the telescope, by turning a screw, so that the light from a small star may not be overpowered by the superior light of the lamp.

The requisites of a good instrument are—1stly, that the telescope be of the best quality, and properly tested; 2ndly, that the feet-screws act well and remain steady; 3rdly, that all the screws, by which the instrument is put together, are turned home, and remain so, after the instrument has been shaken by carriage; 4thly, that the length of the axis be just sufficient to reach from one Y to the other, without either friction or liberty; 5thly, that the lamp be held so as not to require adjustment for position; 6thly, that the screws of adjustment of the diaphragm, and Y's, be competent to give security of position to the parts adjusted by them; 7thly, that the metallic parts be free from flaws in casting, and that the pivots be formed of hard bell-metal, and incapable of rusting.

The principal adjustments of the transit are three:

1st. To make the axis on which the telescope moves horizontal.

2nd. To make the line of collimation move in a great vertical circle, by setting it perpendicular to the horizontal axis.

3rd. To make it move in that vertical circle, which is the meridian.

To make the axis horizontal.—Apply to the pivots the large level, L L, which is supplied with the instrument for this purpose, and is either constructed to stand upon the pivots, in which case it is called a striding level, or suspended from the pivots, and is called a hanging level. Bring the air-bubble to the centre of its run, by turning the foot-screw *f*. Turn the level end for end, and if the air-bubble retains its position, the axis is horizontal; but if not, it must be brought back half by the foot-screw *f*, and the other half by turning the small screw at one end of the level. Repeat the operation till the bubble retains the same position in both positions of the level, and the axis will be horizontal.

To adjust the line of collimation in azimuth.—Direct the telescope to some distant, small, and well-defined object, and bisect it by one extremity of the middle vertical wire, giving the telescope the azimuthal motion necessary for this purpose by turning the screw S. By elevating or depressing the telescope, examine whether the object

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depressed; but in the portable transit the same object is attained by turning one of the foot-screws upon which the entire instrument rests.

is bisected by every part of the middle vertical wire; and, if not, loosen the screws which hold the eye-end of the telescope in its place, and turn the end round very carefully till the error is removed. Lift the transit off the Y's, and reverse it, so that the end of the axis, which was upon the eastern Y, may now be upon the western, and *vice versâ;* and, if the object is still bisected by the central vertical wire, the collimation in azimuth is perfect; but, if not, move the centre of the cross wires half-way towards the object by turning the small screws which hold the diaphragm, and if this half-distance has been correctly estimated, thea djustment will be accomplished. Again, bisect the object by the centre of the cross wires by turning the azimuthal screw S, and repeat the operation till the object is bisected by the centre of the cross wires in both positions of the instrument, and the adjustment will be known to be perfect.*

To adjust the transit to the meridian.—The line of collimation by reason of the previous adjustment describes a vertical circle, and, therefore, bisects the zenith, which is one point in the meridian. If, then, we can make it also bisect another point in the meridian, it will move entirely in the meridian. Compute, from the Tables in the Nautical Almanac, the time of Polaris coming to the meridian, and at the computed time bisect the star by the middle vertical wire, and the transit will be very nearly adjusted to the meridian.

To make the great vertical circle described by the line of collimation more nearly coincident with the meridian, let the intervals between the successive passages of Polaris across the meridian be observed, as indicated by the instrument. Then, if the interval between the inferior and superior passage be equal to the interval between the superior and inferior, the adjustment to the meridian is perfect; but if the interval between the inferior and superior passage be less than the interval between the inferior and superior, the circle described by the line of collimation deviates to the eastward of the true meridian, from the zenith to the north point of the horizon, and to the westward, from the zenith to the south point of the horizon; while if the interval between the inferior and superior passage be the greater, the deviation is in the contrary directions.

Let δ be the observed difference of the intervals from twelve hours, or half the difference between the two intervals in seconds, π the polar distance of the star Polaris, and L the latitude of the place; then, Z representing the deviation from the meridian in time, the value of Z will be given by the logarithmic formula

$$\log. Z = \log. \frac{\delta}{2} + \log. \sec. L + \log. \tan. \pi - 20.$$

EXAMPLE.

Place of observation, Cambridge, latitude 52° 12′ 36″.

Polar distance of Polaris 1° 39′ 25″·05.

Difference of intervals from 12 hours $7^m\ 22^s = 442^s$.

$\frac{\delta}{2} = 221$	log.	=	2·3443923
L = 52° 12′ 36″	log. sec.	=	10·2127030
π = 1° 39′ 25″·05	log. tan.	=	8·4513064
Z = 10^s·195	log.	=	21·0084017

To determine the value of a revolution of the azimuthal screw S, the time of

* The horizontal motion given to the Y, by the azimuthal screw S, forms, evidently, no part of the adjustment for collimation, but only enables us to examine if the adjustment has been made with sufficient exactness.

passage of an equatorial star across the middle vertical wire must be noted one day; and then, turning the screw S once round, the time of passage* must be noted again; and the difference of these times will be the value in time of a revolution of the screw. Suppose the difference thus observed to amount to two seconds, then the value of one complete revolution of the screw S is two seconds, and the value of the motion of the adjusting screw being thus obtained, must be reduced to the horizon, by increasing it in the ratio of cosine of latitude to radius, and may then be applied to correct the error of deviation as found above.

A second method, founded on the same principles as the preceding, consists in observing the pole star, and another star which crosses the meridian near the zenith of the place of observation. The time of passage of such a star, Capella, for instance, when near its superior transit, across the middle wire of the telescope, will differ but very little from the time of passing the true meridian, if the deviation of the instrument from the meridian be but small. Assume the two times to agree exactly, and the difference between the times of superior transit of Capella and Polaris will be the difference of the observed right ascensions of these two stars. From this difference subtract the difference of the computed, or catalogued, right ascensions of the two stars, and call the result D; and the deviation will be given by the formula

$$\log. Z = \log. D + \log. \sin. \pi + \log. \sec. (L + \pi),$$

π being the polar distance of Polaris, and L the latitude of the place of observation. From Capella not having been exactly on the meridian, when on the middle vertical wire, the value of D, as above obtained, is only an approximation to the error of the observed right ascension of Polaris, and the deviation computed from it will be only approximately correct; but, by repeating the operation, the adjustment may be completely perfected.

D is actually the value of the sum of the errors of the observed right ascensions of Capella and Polaris, and hence the value of Z will be correctly given, by so considering it, instead of supposing as above, that this error for Capella is zero. The true deviation then is given by the formula

$$\log. Z = \log. D + \log. \sin. \pi + \log. \sin. \pi' + \log. \text{cosec.} (\pi' - \pi) + \log. \sec. L,$$

π' being the polar distance of Capella.

Using this last formula, the method may be applied to Polaris, and any star distant from the pole, or to any two stars differing from each other not less than 40° in declination. If, however, the transit of one star is observed above, and of the other below the pole, the formula will be

$$\log. Z = \log. D + \log. \sin. \pi + \log. \sin. \pi' + \log. \text{cosec.} (\pi' + \pi) + \log. \sec. L.$$

Considerable advantage may be obtained by selecting two stars that differ but little in right ascension, as there is then the less probability of error from a change in the rate of the clock, or in the position of the instrument, on which account such methods are to be preferred in temporary observatories, where the stability of the instrument is not to be depended upon for any length of time.

In all the preceding formulæ, the deviation from the meridian is given in time; but to convert it into angular measure, if desirable, we have only to multiply by 15, and the seconds of time will be converted into seconds of a degree.

When the instrument is by any of the methods explained above brought into the

* The time here spoken of, and throughout the description of this instrument, unless otherwise expressly stated, is sidereal, and not mean time.

meridian, a distant mark may be set up in the plane of the meridian, by which the adjustment to the meridian may afterwards be tested.

Method of observing with the transit.—The adjustments having been completed, in making observations with the instrument, the instant of a star's passing the middle vertical wire will be the time of the star's transit; but the time of the star's passing all the five wires must be noted, and the mean of the times, taken as the time of transit, will be a more accurate result than the time observed at the middle wire only.

When the sun is the object observed, the time of the centre of his disc passing the middle wire is the time of transit; but as it would be impossible to estimate this centre with accuracy, the time of both his limbs coming into contact with each wire in succession is to be noted, and a mean of all these times will be the time of transit required. This mean may be conveniently taken, by writing the observed times of contact of the first and second limbs underneath each other in the reverse order, when the sums of each pair will be nearly equal.*

EXAMPLE.

	s	s	h m s	s	s	
1826. Sept. 23.	20·4	38·7	11 58 57·0	15·5	33·7	☉ 1 limb.
	42·3	24·0	12 1 5·7	47·2	28·7	☉ 2 limb.
	2·7	2·7	24 0 2·7	2·7	2·4	The sum = 13·2

The time of either limb passing the centre wire is recorded in full, but for the other wires, the seconds only are recorded, as the sums of the several pairs only differ by decimals of a second. Half the sum of the times at the middle gives, then, the correct time of transit as far as the seconds, and the decimals are found by removing the decimal point one place to the left in the sum 13·2, which is equivalent to dividing by 10. Then the time of transit, or mean of observations in the above example, is $12^{h}\ 0^{m}\ 1^{s}{\cdot}32$. This example is taken from observations made with a large transit; and, if with a smaller instrument the sums of the several pairs of observations should differ by more than a second, it will be necessary to take the sums of both figures of the seconds, and the division by 10, performed as above, will give the last figure of the seconds, as well as the decimals.

In taking transits of the moon, the luminous edge alone can be observed, from which the time of transit of the centre must be deduced by the aid of Lunar tables.

In observing the larger planets, one limb may be observed at the first, third, and fifth wires, and the other at the second and fourth, and the mean of these observations will give the transit of the planet's centre.

It will sometimes happen that from the state of weather, or from some other cause, a heavenly body may not have been observed at all the wires; but if the declination of the body be known, an observation at any one of the wires may be reduced to the central wire, so as to give the time of transit, as deduced from this observation. If an observation be obtained at more than one wire, the mean of the times of passing the centre, as deduced from each wire observed, is to be taken as the time of transit. The reduction to the centre wire is given by the formula

$$R = V \operatorname{cosec.} \pi, \text{ or } \log. R = \log. V + \log. \operatorname{cosec.} \pi;$$

in which R represents the reduction, π the polar distance of the body observed, and

* This is Dr. Pearson's method.

V the equatorial interval from the wire, at which the observation has been made, to the central wire. The equatorial intervals for each side wire must, therefore, be carefully observed, and tabulated for the purpose of this reduction. The formula $R = V$ cosec. π is only an approximate value of the reduction, and with large instruments capable of giving results within $0''\cdot05$, a further correction is necessary for bodies within $10°$ of the pole. The whole reduction in this case is given by the formula

$$R' = \tfrac{1}{15} \sin.^{1} 15 \text{ V cosec. } \pi.$$

The time of any star's passage from one of the side wires to the centre wire being observed, the equatorial interval from that wire to the centre is obtained by multiplying the observed interval by the sine of the star's polar distance; and the equatorial intervals being deduced in this manner from a great many stars, the mean of the results may be considered as very correct values of the equatorial intervals required. No star very near the pole should, however, be taken for this purpose.

Use of the portable transit.—The large transits in permanent observatories are used to obtain, with the greatest possible accuracy, the right ascensions of the heavenly bodies, from which, and the meridian altitudes observed by a mural circle, an instrument consisting of a telescope attached to a large circle, and placed in the plane of the meridian, nearly all the data necessary for every astronomical computation are obtained. For such purposes the small portable transit is not adapted; but it is competent to determine the time to an accuracy of half a second, to determine the longitude by observations of the moon and moon culminating stars, and to determine the latitude by placing it at right angles to the meridian, or in the plane of the prime vertical. *

The transit of the sun's centre gives the apparent noon at the place of observation, and the mean time at apparent noon is found by subtracting or adding the equation of time, as found in the Nautical Almanac, to 24 hours. † The difference between the mean time, thus found, and the time of the sun's transit, as shewn by a clock or chronometer, is the error of the clock or chronometer for mean time at the place of observation.

The time shewn by a sidereal clock when any heavenly body crosses the meridian should coincide with the right ascension of that body, as given in the Nautical Almanac. The difference between the time shewn by the sidereal clock, at the transit, and the right ascension of the body, taken from the almanac, will, therefore, be the error of the clock, +, or too fast, when the clock time is greater than the right ascension, − or too slow, when it is less.

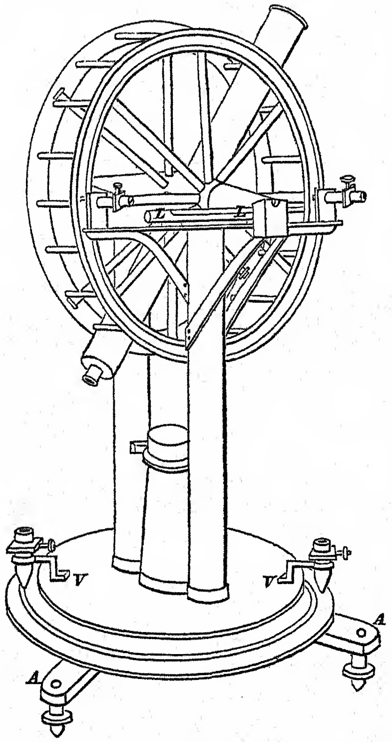
The Portable Altitude and Azimuth Instrument.—The bending of an unbraced telescope renders it unfit for the determination of altitudes; but by placing the telescope between two circles braced together, an instrument may be formed capable of observing both the meridian altitudes and times of transit of the heavenly bodies. The increased weight of the instrument, however, must now be prevented from producing flexure in the horizontal axis, and this has been very ingeniously accomplished by Troughton. By mounting the transit and altitude instrument, as Troughton's transit-circle may be called, upon a horizontal plate or circle having an

* The prime vertical is the great circle which passes through the zenith and the east and west points of the horizon.

† The astronomical day commences at noon, and contains 24 hours, the hours after midnight being called 13, 14, &c., and the day ends at the next noon. The equation of time is given in the Nautical Almanac for apparent noon at the meridian of Greenwich, and the correction to give the equation of time at any other meridian will be found by multiplying the difference for one hour, as given in the almanac, by the longitude of the place, estimated in time.

azimuthal motion round a vertical axis, an instrument is formed by which observations may be made either in or out of the meridian. When constructed of a portable size, the altitude and azimuth instrument may also be used in important surveying operations; for, in fact, it may be considered as a rather large theodolite of superior construction.

The altitude and azimuth instrument may be considered as consisting of three parts: 1, the tripod carrying the vertical axis about which the instrument turns; 2, the horizontal revolving plate carrying the vertical pillars, with their appendages; and 3, the vertical circles with the telescope.



The tripod, A A, is supported by three foot-screws, by which the vertical axis is brought into adjustment, and carries the lower horizontal plate, which is graduated to shew the azimuths or horizontal angles. The vertical axis is a solid metallic cone rising from the centre of the tripod to a height about equal to the radius of the horizontal circle.

The upper horizontal plate, or horizontal revolving plate, V V, carries an index, to point out the graduation, upon the lower horizontal plate, or azimuth circle, which denotes nearly the angle to be read off. The graduations upon the azimuth circle, as well as upon the vertical circle, are subdivided by reading microscopes, the construction and adjustments of which we shall presently explain. The reading microscopes of the azimuth circle are attached to the revolving plate V V, which also carries two upright pillars. From the centre of the upper horizontal plate, V V, rises a hollow brass cone which just fits over and moves smoothly upon the solid metallic vertical axis rising from the tripod stand. A horizontal brace connects the two upright pillars with one another and with the top of the hollow brass cone, and keeps the pillars firm and parallel to one another. On the top of each pillar a gibbet piece is fixed, projecting beyond the pillars, and upon the extreme ends of these pieces are carried the Y's for supporting the pivots of the horizontal, or transit axis. The Y's are each capable of being raised or lowered by turning a milled-headed screw. The top of one of the pillars carries a cross piece for supporting the two reading microscopes of the vertical circle; and to this cross piece is attached the level L L, by which the adjustment of the vertical axis is denoted.

The third portion of the instrument consists of the vertical circle and its telescope. This circle consists of two limbs firmly braced together, and preventing any tendency to flexure in the tube of the telescope, by affording it support at the opposite ends of a diameter. One of the limbs only is graduated, and the graduated side is called the face of the instrument, and the clamp and tangent screw, for giving a slow motion

to the vertical circle, act upon the ungraduated limb, and are fixed to the vertical pillar on the side of that limb. The horizontal axis which supports the telescope and vertical circle is constructed exactly as the axis of the transit instrument; but as it might press too heavily on the Y's from the increased load of the vertical circle, a spiral spring, fixed in the body of each pillar, presses up a friction roller against the conical axis with a force which is nearly a counterpoise to its weight. The adjustment of the horizontal axis is denoted by a striding level, as in the portable transit.

ADJUSTMENTS.

Adjustments of the vertical axis.—Turn the instrument round till the level, L L, is over two of the foot-screws, and adjust the level, so that its bubble may retain the same position, when the instrument is turned half-round, so that the level is again over the same foot-screws, but in the reverse position. The error at each trial is corrected, as nearly as can be judged, half by the foot-screws, and half by the adjusting screw of the level itself.

Next turn the instrument round 90° in azimuth, so that the level, L L, may be at right angles to its former positions, and bring the bubble to the same position as before, by turning the third foot-screw. Repeat the whole operation till the result is satisfactory.

Adjustment of the horizontal axis.—This adjustment is performed in the same manner, as already described for the transit instrument, with the single exception that one end of the axis is to be raised or lowered, if necessary, by the screw acting upon its Y, and not by moving a foot-screw, which would derange the previous adjustment.

Adjustment of the circle to its reading microscopes.—This is performed by raising or lowering both the Y's equally, so as not to derange the previous adjustment, till the microscopes are directed to opposite points in its horizontal diameter.

Adjustment of collimation in azimuth.—Instead of taking the axis out of its bearings and turning it end for end, the whole instrument is turned round in azimuth; but in all other respects the method of performing this adjustment is the same as that already described for the transit instrument.

Adjustment of collimation in altitude.—Point the telescope to a very distant object, or star, and, bisecting it by the cross wires, read off the angle upon the vertical circle denoted by the reading microscopes. Turn the instrument half-round in azimuth, and, again bisecting the same object by the cross wires, read off the angle. One of these readings will be an altitude, and the other a zenith distance,* and their sum, therefore, when there is no error of collimation in altitude, will be 90°. If the sum is not 90°, half its difference from 90° will be the error of collimation in altitude, and this error being added to or subtracted from the observed angles, according as the sum of the readings is less or greater than 90°, will give the true zenith distance and altitude. The error of collimation in altitude may then be corrected by adjusting the microscopes to read the true zenith distance and altitude, thus found, while the object is bisected by the cross wires of the telescope. The error of collimation of this and other astronomical instruments may also be found, or corrected, by the collimator.

Use of the altitude and azimuth instrument.—In using the altitude and azimuth instrument, for astronomical purposes, double observations should always be made, with the face first to the east, and then to the west, or *vice versâ*, or several observa-

* Both the horizontal and vertical circles are usually divided alike into four quadrants, and each quadrant graduated from 0° to 90°, proceeding in the same direction all round the circles.

tions may be made with the face to the east, and as many with the face to the west, and the mean of the results, reduced to the meridian, taken as the true results. The place for a meridian mark may be determined by the methods already explained when describing the transit instrument, or by observing the readings of the azimuthal circle, or noting the times, when any celestial object has equal altitudes. Since the diapraghm of the telescope is furnished not only with the central horizontal wire, but with other horizontal wires at equal distances above and below it, so that there may be altogether either three or five or seven horizontal wires, the azimuths and times may be observed, when the object observed is bisected by each of these wires. If a fixed star be the object observed, the mean of the times will give the time of the star's passing the meridian, and the mean of the azimuths will give the reading of the azimuth circle when the star was on the meridian, or the correction to be applied to the readings of the azimuth circle to give the true azimuths. If the sun be the body observed, a correction is necessary on account of the change of his declination, during the intervals between the observations.

The correction for the time, as deduced from a pair of equal altitudes of the sun, is given by the formula,

$$\text{Correction} = \frac{\delta}{720} \times \frac{\frac{t}{2}}{\sin.\ 15^\circ \cdot \frac{t}{2}} (\tan.\ D \times \cos.\ 15^\circ \cdot \tfrac{t}{2} - \tan.\ L), \text{ in which}$$

δ represents the variation in the sun's declination from the noon of the day preceding the observations to the noon of the day succeeding;

t represents the interval between the observations expressed in hours and decimals of an hour;

D represents the sun's declination at noon on the day on which the observations are made;

L represents the latitude of the place.

δ is to be reckoned positive when the sun's declination is increasing, and negative when it is decreasing.

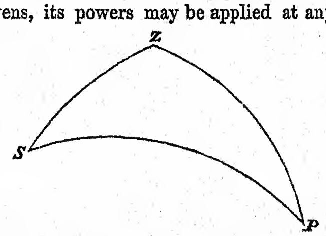
The correction for azimuth is given by the formula,

$$\text{Correction} = \tfrac{1}{2}(D' - D) \sec.\ \text{lat.} \ \text{cosec.} \frac{15}{2}(T' - T),$$

in which $D' - D$ represents the change of the sun's declination, and $T' - T$ represents the interval in time, $\Big\}$ between the observations.

When the sun is advancing towards the North Pole, this correction will carry the middle point towards the west of the approximate south point; but when he is approaching the South Pole, it will carry the same point towards the east, and must be applied accordingly.

The altitude and azimuth instrument being adapted to observe the heavenly bodies in any part of the visible expanse of the heavens, its powers may be applied at any time to determine the data from which the time, the latitude of the place of observation, or the declination of the body observed, may be at once determined. We subjoin some of the formulæ, adapted to logarithmic computation, connecting the parts of what may be called the *astronomical triangle*, of which the points are, the pole, P, the zenith, Z, and the apparent place of the body observed, S.

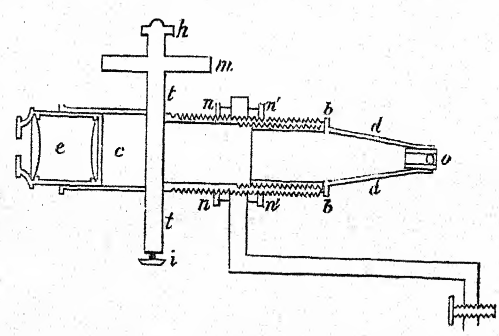


Let P Z, the co-latitude of the place, be represented by λ.
P S, the polar distance of the body observed, ... π.
Z S, the zenith distance of the body observed, ... Z.
Z P S, the hour-angle from the meridian, ... h.
P Z S, the azimuthal angle, ... α.

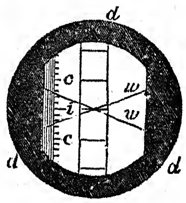
Then we have the following formulæ for determining the time, the latitude, and the declination of the body observed.

No.	Given.	Required.	Auxiliary Angles.	Formulæ.
1	Z, π, λ	h	.. .. ..	$\tan. \frac{1}{2} h = \sqrt{\frac{\sin. \frac{1}{2}(Z+\pi-\lambda) \cdot \sin. \frac{1}{2}(Z+\lambda-\pi)}{\sin. \frac{1}{2}(Z+\pi+\lambda) \cdot \sin. \frac{1}{2}(\pi+\lambda-Z)}}$
2	π, λ, α	h	$\tan. \phi = \frac{\cot. \alpha}{\cos. \lambda}$	$\cos. (h \sim \phi) = \frac{\cot. \pi \cos. \phi}{\cot. \lambda}$
3	Z, λ, α	h	$\cot. \phi = \frac{\cot. Z}{\cos. \alpha}$	$\cot. h = \frac{\cot. \alpha \sin. (\lambda \sim \phi)}{\sin. \phi}$
4	Z, π, α	h	.. .. ..	$\sin. h = \frac{\sin. Z \sin. \alpha}{\sin. \pi}$
5	Z, π, α	λ	$\tan. \phi = \cos. \alpha \tan. Z$	$\cos. (\lambda \sim \phi) = \frac{\cos. \pi \cos. \phi}{\cos. Z}$
6	Z, π, h	λ	$\tan. \phi = \cos. h \tan. \pi$	$\cos. (\lambda \sim \phi) = \frac{\cos. Z \cos. \phi}{\cos. \pi}$
7	Z, α, h	λ	$\cot. \phi = \frac{\cot. Z}{\cos. \alpha}$	$\sin. (\lambda \sim \phi) = \frac{\cot. h \sin. \phi}{\cot. \alpha}$
8	π, α, h	λ	$\cot. \phi = \frac{\cot. \pi}{\cos. h}$	$\sin. (\lambda \sim \phi) = \frac{\cot. \alpha \sin. \phi}{\cot. h}$
9	Z, λ, α	π	$\tan. \phi = \cos. \alpha \tan. Z$	$\cos. \pi = \frac{\cos. Z \cos. (\lambda \sim \phi)}{\cos. \phi}$
10	Z, λ, h	π	$\tan. \phi = \cos. h \tan. \lambda$	$\cos. (\pi \sim \phi) = \frac{\cos. Z \cos. \phi}{\cos. \lambda}$
11	Z, α, h	π	.. .. ..	$\sin. \pi = \frac{\sin. \alpha \sin. Z}{\sin h}$
12	λ, α, h	π	$\tan. \phi = \frac{\cot. \alpha}{\cos. \lambda}$	$\cot. \pi = \frac{\cot. \lambda \cos. (h \sim \phi)}{\cos. \phi}$

The Reading Microscope.—The first of the annexed figures represents a longitudinal section of this instrument, and the second represents the field of view, shewing the magnified divisions of the limb of the instrument to which the microscope is applied, and the diaphragm, $d\,d$, of the microscope, with its comb, $c\,c$, and cross wires, $w\,w$. The diaphragm is contained in the box, $t\,t$, and consists of two parts moving one over the other,—the comb $c\,c$, which is moved by the screw i, at the bottom of the



box, for the purpose of adjustment, and the cross wires *w w*, and index *i*, which are moved over the comb and the magnified image of the limb, by turning the milled head *h*. The micrometer head, *m*, is attached by friction to the screw turned by the milled head, so that, by holding fast the milled head, the micrometer head can be turned round for adjustment.



e is the eye-piece, which slides with friction into the cell *c*, so as to produce distinct vision of the spider's lines of the micrometer. The object-glass, *o*, is held by a conical piece *d d*, which screws further into, or out of, the body of the instrument, so as to produce distinct vision of the divided limb to be read by the microscope, and, when adjusted, is held firmly in its place by the nut *b b*. The microscope screws into a collar, so as to be capable of adjustment with respect to its distance from the divided limb, and, when so adjusted, is held firmly in its place by the nuts *n n*, *n′ n′*.

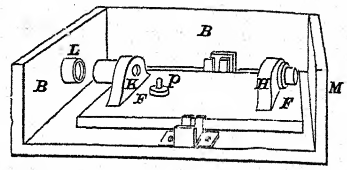
Adjustments of the reading microscope.—Screw the object-glass home. Insert the body of the microscope into the collar destined to receive it, and screw home the nuts *n n* and *n′ n′*. Make the diaphragm and spider's lines visible distinctly, by putting the eye-piece *e* the proper depth into the cell *c*. Then make the graduated limb also distinctly visible without parallax by turning the nuts *n n* and *n′ n′*, unscrewing one and screwing up the other till the desired object is attained.

Now bring the point of intersection of the spider's lines upon a stroke of the limb, and turn the micrometer head *m* to zero; then, turning the screw through five revolutions, if the point of intersection of the spider's lines has not moved over the whole of one of the divided spaces on the limb, the object-lens must be screwed up to diminish the power by turning the cone *d d*; and if it has moved over more than one of the divided spaces, it must be unscrewed to increase the power; and then altering the position of the microscope, by turning the nuts *n n* and *n′ n′*, till distinct vision of the limb is again obtained, the measure of the space, moved over by five revolutions of the screw, must be repeated, as before. When, after repeated trials, the result is satisfactory, the three nuts, *n n*, *n′ n′*, and *b b*, must be screwed tight home, to render the adjustment permanent.

When the microscope has been thus adjusted for distance, the zero of the division on the limb must be brought to the point of intersection of the spider's lines, and the divided head, *m*, turned, till its zero is pointed to by its index; and then, if the zero on the comb, *c c*, be not covered exactly by the index *i*, the comb must be moved by turning the screw *i*, which enters the bottom of the micrometer box, till its zero is covered by the index pin. The adjustment of the reading microscope will now be perfect; and the graduated limb to be read by it, being divided at every five minutes, the degree and nearest five minutes of an observed angle will be shewn by the pointer or index to this graduated limb; while the number of complete revolutions, and the parts of a revolution, of the screw, in the order of the numbers upon the micrometer head, *m*, required to bring the point of intersection of the spider's lines upon a division of the graduated limb, will be the number of minutes and seconds, respectively, to be added to the degrees and minutes shewn by the index of the circle. The complete revolutions, or minutes, to be added, are shewn by the number of teeth the index *i* has passed over from zero, and the parts of a revolution, or seconds and tenths to be added, are pointed out upon the micrometer head, *m*, by its index.

The Collimator.—B B is a rectangular mahogany box partly filled with mercury. F F is a float of cast iron partly immersed in the mercury. *b b* are two iron bearing pieces, screwed to the bottom of the box by short iron screws; and each of these

pieces has two vertical plates turned up, the inner one of which has a longitudinal slit in it, into which slit iron pivots, screwed into the sides of the float, are admitted. The use of these parts is to keep the sides of the float parallel to the sides of the box, and at an inch, or more, from contact with any part of the box, that the mercury may assume a flat surface. H and K are two holding pieces of metal cast along with the float, and are perforated to receive each a socket. The socket at H receives an achromatic object-glass, and is adjustable by a screw for its focal distance, and the socket at K holds two cross wires;



while another socket, let into the end of the box at L, carries a lens forming an eye-piece; so that the collimator is in fact an astronomical telescope with a system of cross wires in the common focus of the object-glass and eye-lens. The inclination, as compared with the surface of the fluid, of the optical axis of this telescope, or of the line joining the centre of the object-glass and the intersection of the cross wires can be modified by the addition of perforated pieces of iron, held steady by the vertical pin P, and by their weight depressing the end of the float. The mercury must be as pure as can be obtained, and particles of dust must be constantly excluded by a lid that covers over the top of the box. At M is a circular hole, closed when the instrument is not in use, through which the telescope, of which the error of collimation is sought, is to be directed; and a lamp is placed behind the eye-lens at L, to illuminate the cross wires.

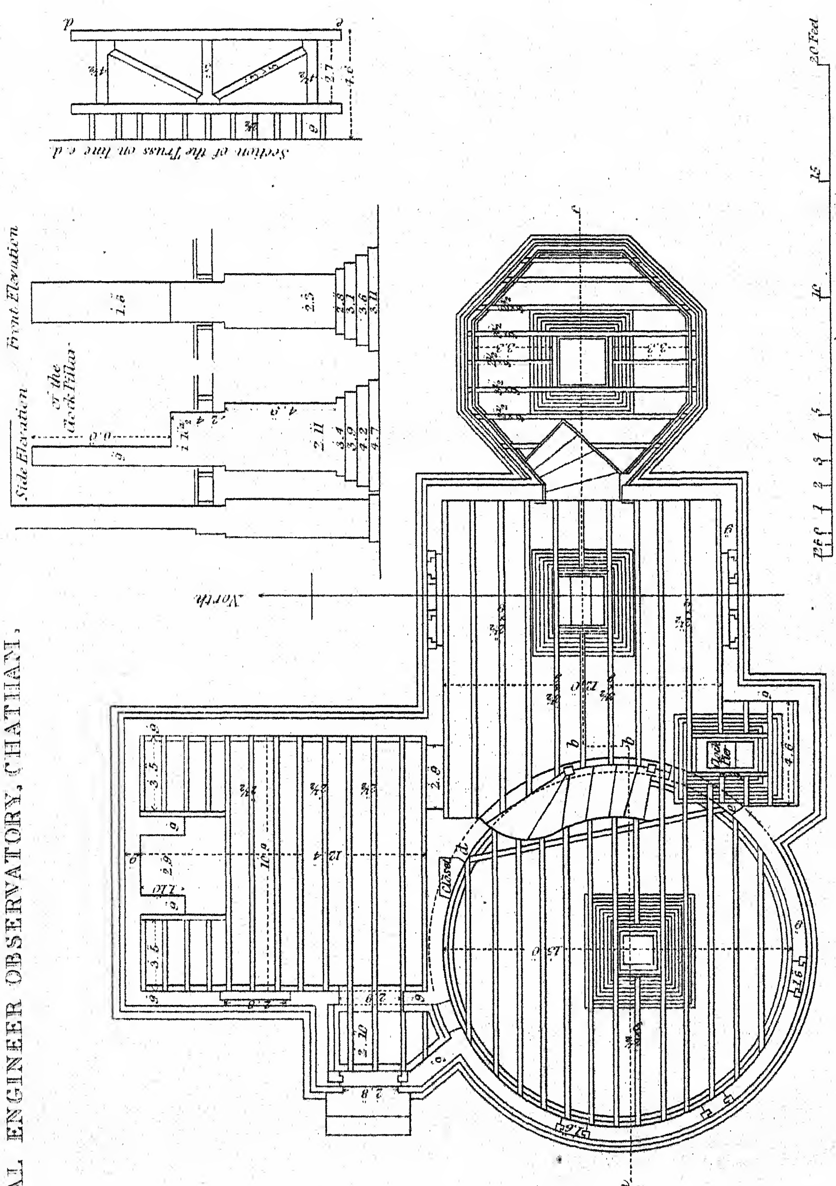
Use of the collimator with an altitude and azimuth instrument.— Place the collimator in the plane of the meridian on the south side of the observatory, and direct it so that the cross wires of the telescope of the altitude and azimuth instrument may be seen through it, in the centre of the field of view; then also will the cross wires of the collimator be seen through the telescope in the centre of its field of view. Read off the altitude of the cross wires of the collimator, and then, turning the instrument half-round in azimuth, observe again the cross wires of the collimator, and read off the angle upon the vertical limb, which will now be a zenith distance. The difference between the sum of these readings and 90° is the correction which is to be applied to the altitudes and zenith distances observed with the instrument.

Example.—The sun's meridian altitude had been observed on the 20th December, 1826, and the following determination of the error was made immediately after the observations were finished; viz.

Before reversion the apparent altitude of the cross wires was .		0°	1′	2″·33
After reversion the apparent zenith distance of the cross wires was		89	58	10 ·33
Sum		89	59	12 ·66
Defect from 90°				47 ·33
Correction of errors of collimation &c. . .				23 ·66
Altitude of cross wires corrected	$= \left\{ \begin{matrix} & 1' & 2''{\cdot}33 \\ + & & 23\ {\cdot}66 \end{matrix} \right\} =$		1	26 ·00
Zenith distance	$= \left\{ \begin{matrix} 89° & 58' & 10''{\cdot}33 \\ + & & 23\ {\cdot}66 \end{matrix} \right\} =$	89	58	34 ·00
		90	0	0 ·00

The collimator may also be used for a meridian mark with the transit instrument. When used with a circle for measuring altitudes and zenith distances, which has no motion in azimuth, the collimator must be moved from the north to the south side of the observatory, and the mean of the observations in each of these two positions will give the correction for the errors of collimation, &c., as above.

J. F. H.



Taken from the 7th Vol. of Professional Papers

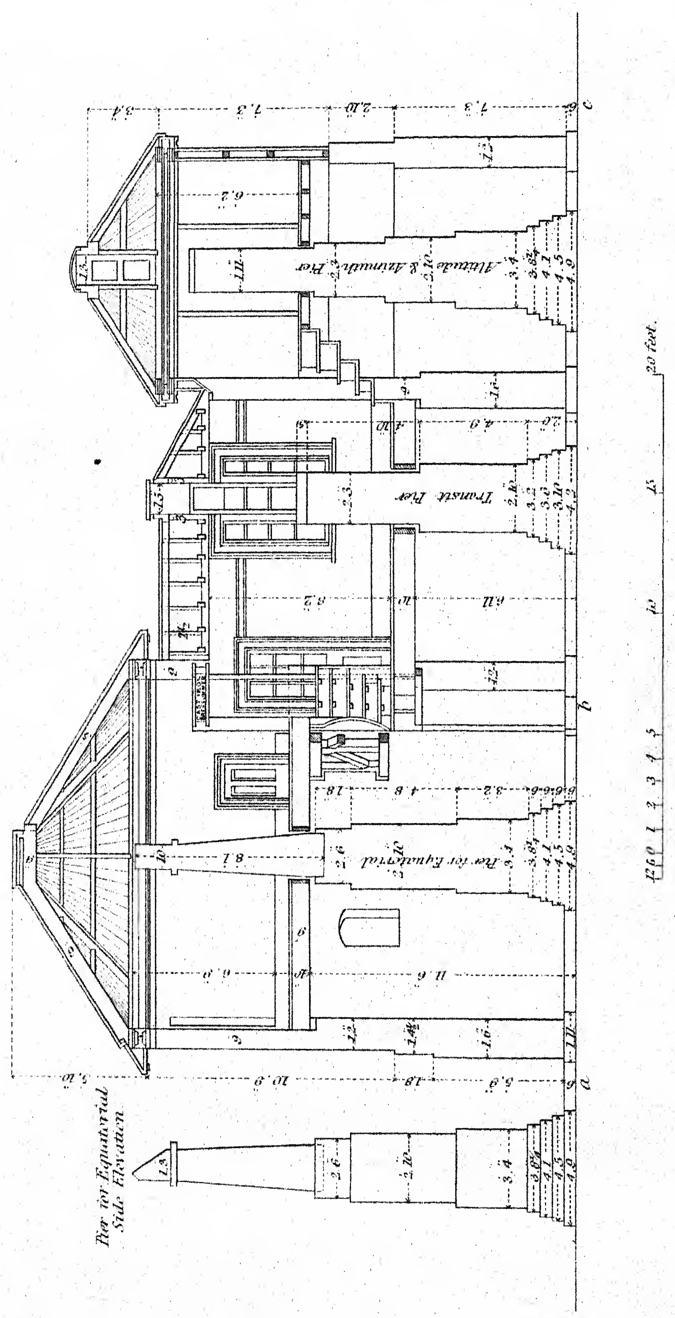
J.W. Lowry fc.

London, John Weale, High Holborn, 1849.

ROYAL ENGINEER OBSERVATORY, CHATHAM.

Section on the Line a. b. b. c. Plate 1.

Through the Equatorial Transit and Altitude and Azimuth Rooms.



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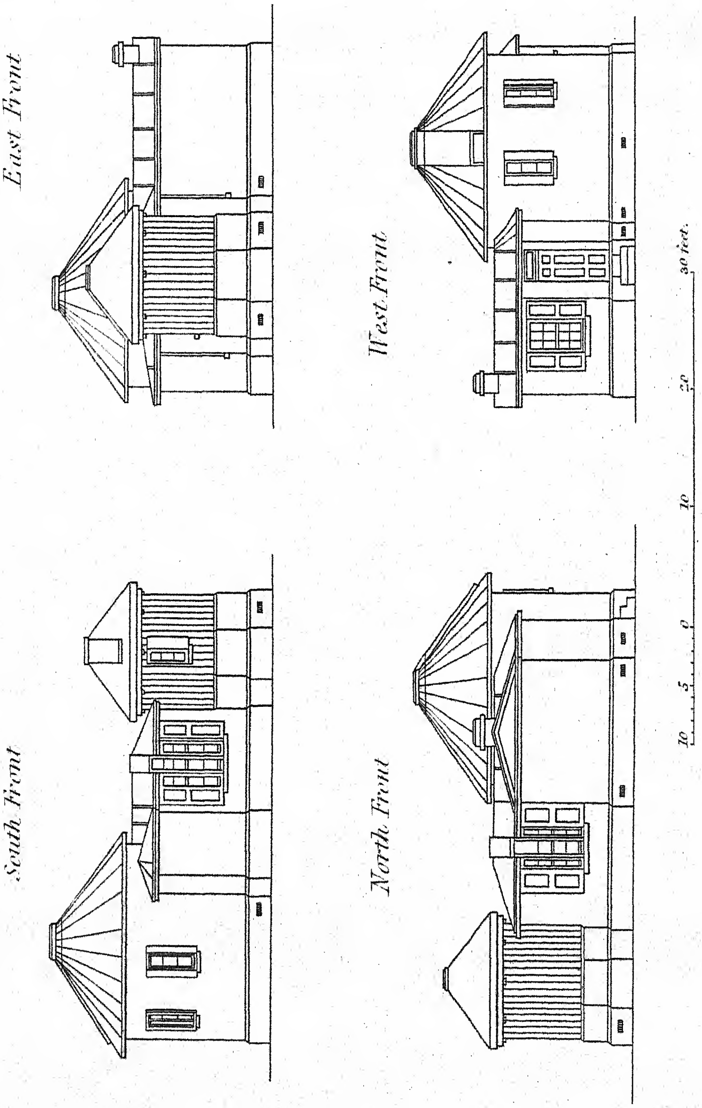

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ROYAL ENGINEER OBSERVATORY, CHATHAM.

Fig. 1.

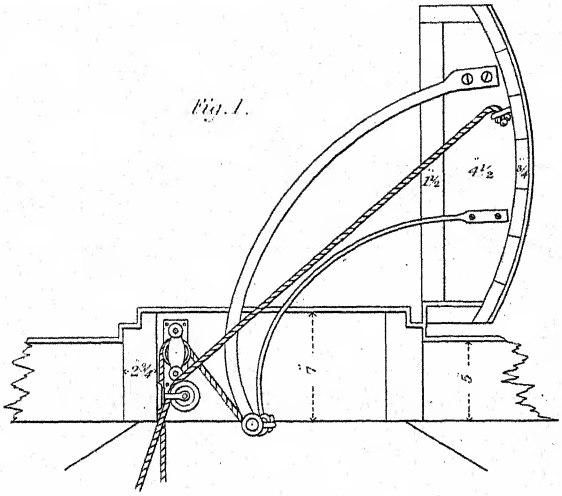


Fig. 2.

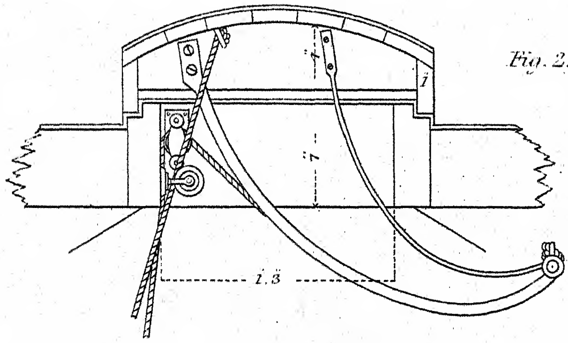


Fig. 3.

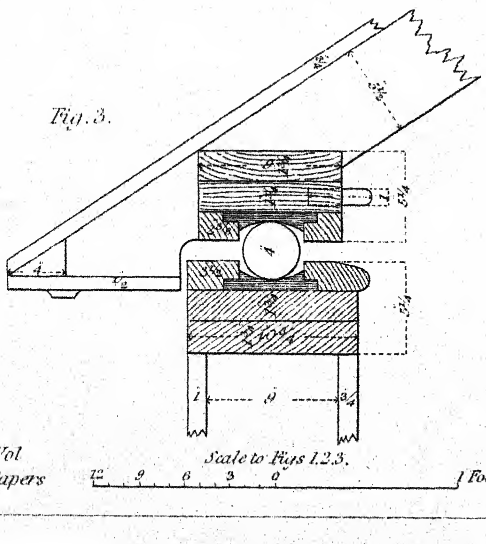


Fig. 1 Is a Section through the top of the Dome Open
2 do do Shut
Fig. 3 Shews the construction of the lower part of the dome and how it is supported upon the walls: six balls are used, M is one of the oak pins which are placed at intervals of 6½ inches round the dome for a lever to work against in turning it round.

Taken from the 7th Vol of Professional Papers

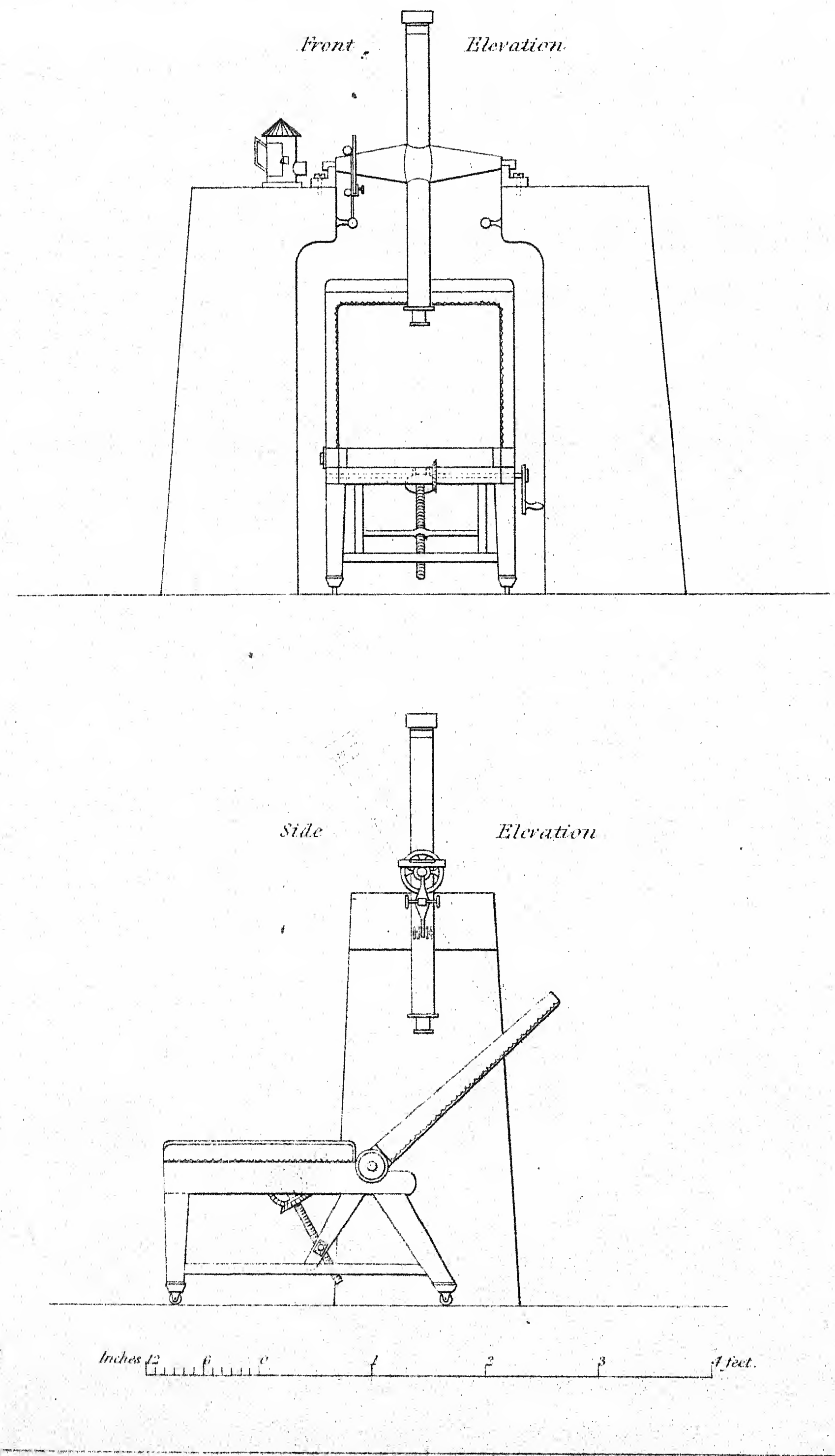
Scale to Figs 1.2.3.

12 9 6 3 0 1 Foot

J. W. Lowry fc.

London, John Weale High Holborn 1849.

PROPOSED METHOD OF MOUNTING THE SMALLER CLASS OF TRANSIT INSTRUMENTS.



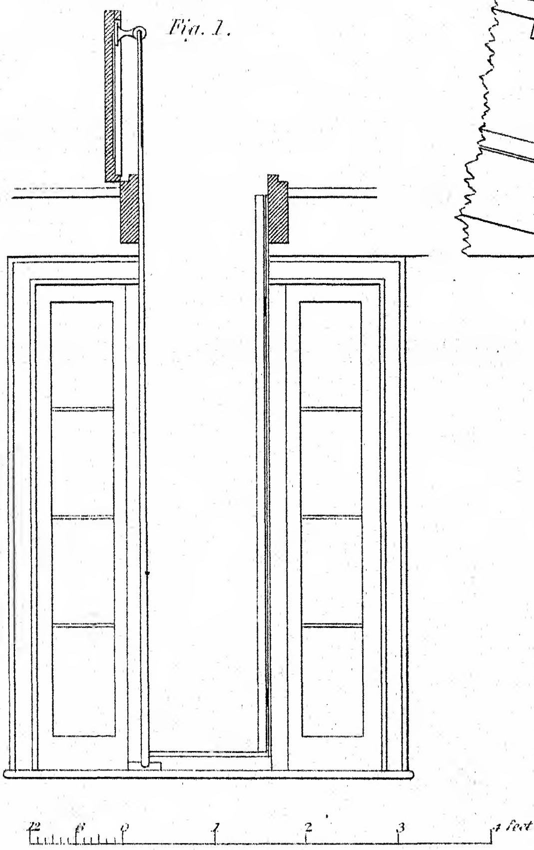
J.G.M. J.W. Lowry fc.

London. John Weale. High Holborn. 1849.

SHEWING THE METHOD OF OPENING AND KEEPING OPEN THE TRANSIT SHUTTERS R.E. OBSERVATORY CHATHAM.

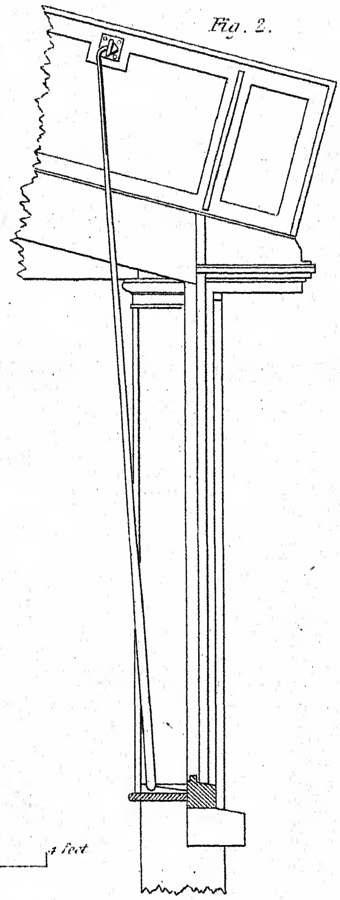
Front Elevation

Fig. 1.



Side Elevation

Fig. 2.



Sections thro' the Shutters of the Equatorial Dome Royal Engineer Observatory Chatham.

Fig. 3.
Shutter Shut

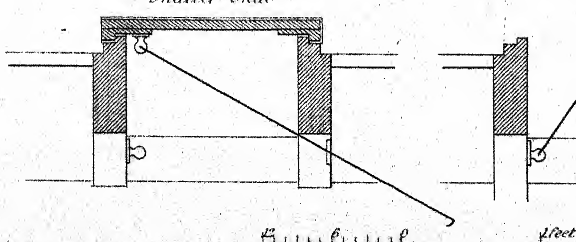
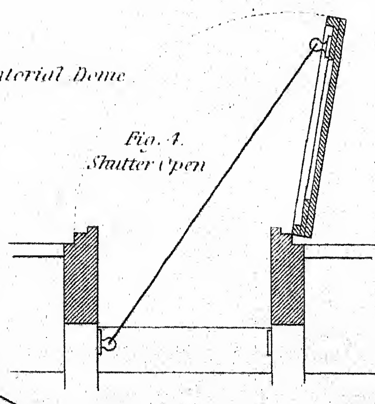


Fig. 4.
Shutter Open



J.G.M.

J.W. Lowry fc.

London, John Weale, High Holborn, 1840.

ELEVATION AND SECTION OF THE CURB AND MOVING LEVERS OF THE EQUATORIAL DOME R. E. OBSERVATORY CHATHAM.

Fig. 1.

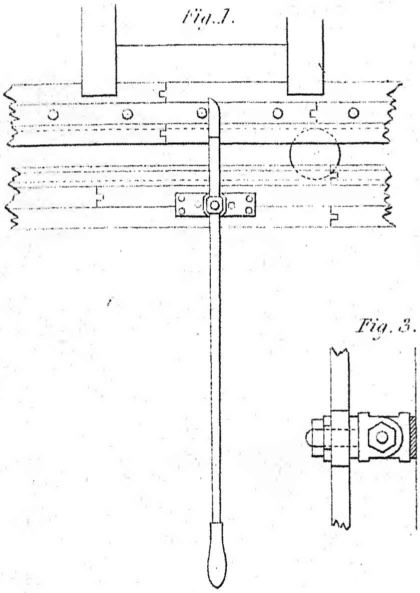


Fig. 2.

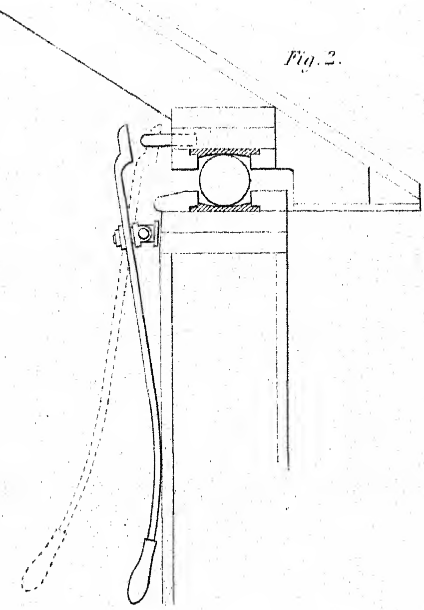


Fig. 3.

Elevation and Section of the curb and hand pins of the small Dome Royal Engineer Observatory.

Fig. 4.

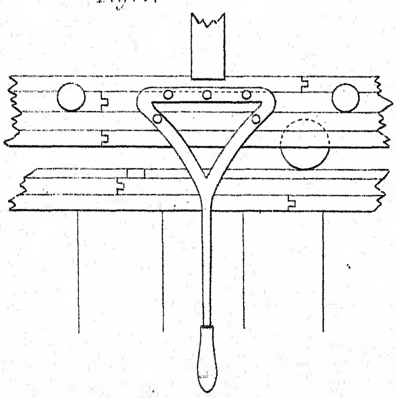
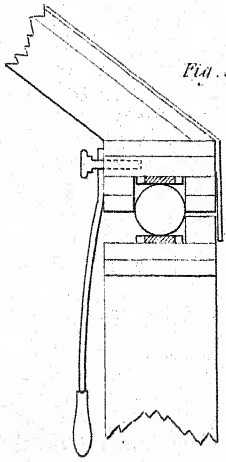
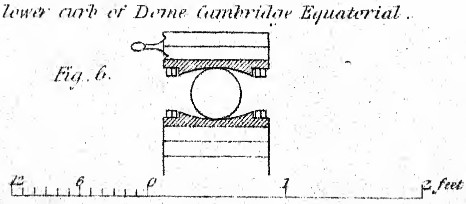


Fig. 5.



Section of the wall curb and lower curb of Dome Cambridge Equatorial.

Fig. 6.



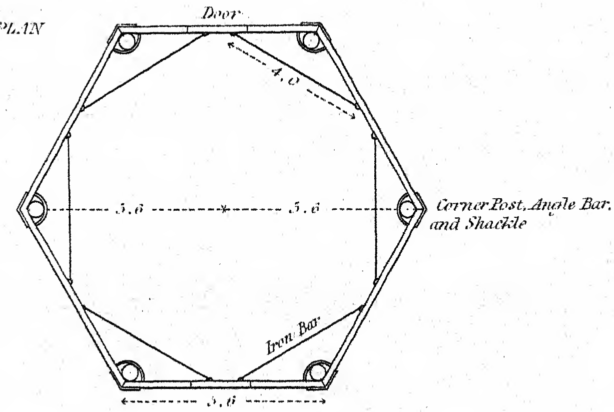
J. G. M. J. W. Lowry fc.

London, John Weale, High Holborn 1849.

PORTABLE OBSERVATORY.

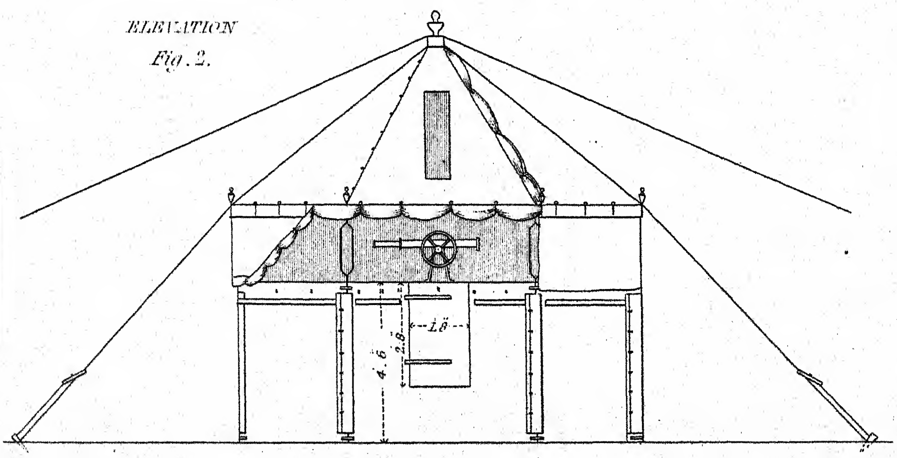
Used on the Ordnance Survey for the largest clafs of Theodolites Viz. the 3 Feet.

GROUND PLAN
Fig. 1.



Shewing part of Curtain rolled up and side of Roof open for observing the Pole Star.

ELEVATION
Fig. 2.



Scale of Feet

10 5 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 feet

J. W. Lowry fc.

London, John Weale, High Holborn, 1848.

PORTABLE OBSERVATORY.

SKELETON SECTION of Fig. 2. shewing four out of the six Upright Posts and Rafters.

Fig. 3.

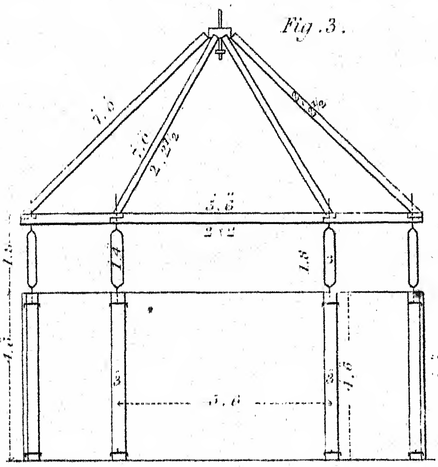


Fig. 4.

Inside View of Panel

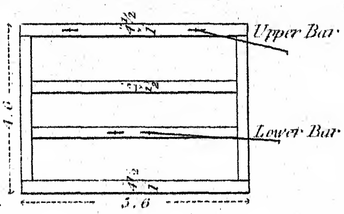


Fig. 5.

Fig. 6.

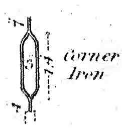
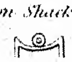


Fig. 7.

Iron Angle Bar

Fig. 8.

Iron Shackle



J. W. Lowry fc.

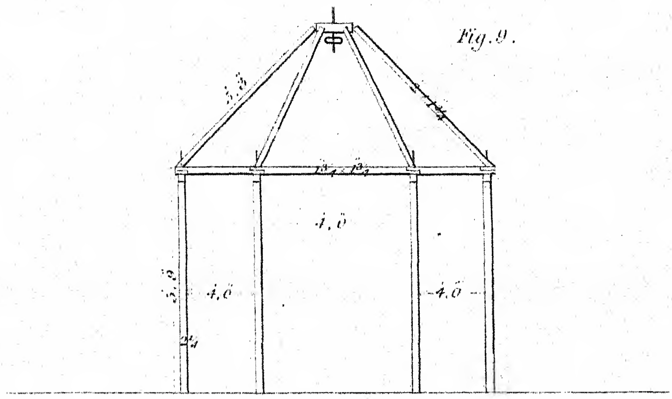
London, John Weale, High Holborn

PORTABLE OBSERVATORY

Used on the Ordnance Survey for the 12 inch or 10 inch Theodolites.

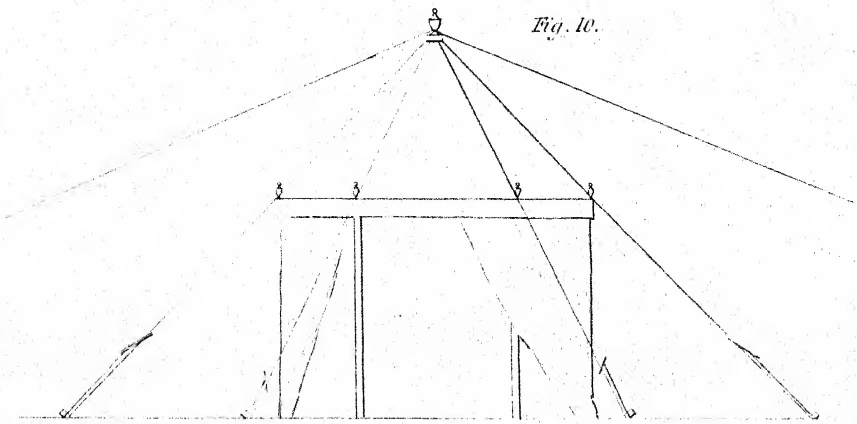
SKELETON SECTION.

Fig. 9.

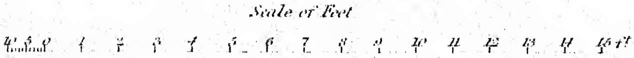


FRONT VIEW

Fig. 10.



Scale of Feet



J.W. Lowry fc.

London John Weale, High Holborn 1849.

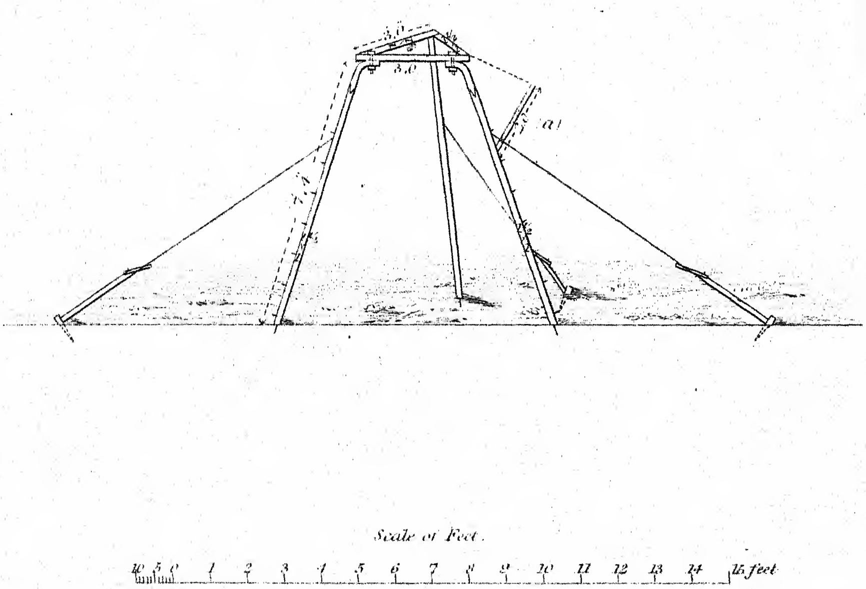
PORTABLE OBSERVATORY.

Used on the Ordnance Survey for the smaller Theodolites

Viz. the 7 Inch &c.

Fig. II.

SUPPORT FOR THE CANVAS



(a) A piece of Stick or Wood 2 feet long notched at foot for Canvas head when required lifting.

J. W. Lowry fc.

London, John Weale High Holborn, 1849.

PORTABLE OBSERVATORY

for the Zenith Sector

Fig. 12.

GROUND FRAME.

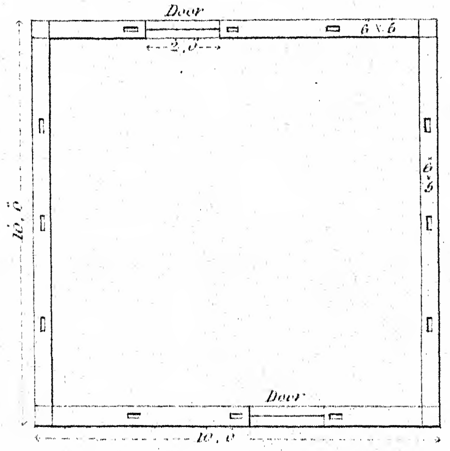
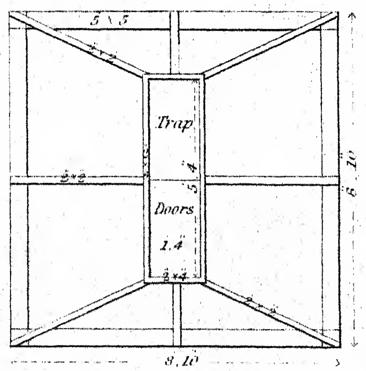


Fig. 13.

TOP FRAME & RAFTERS.



J. W. Lowry fc.

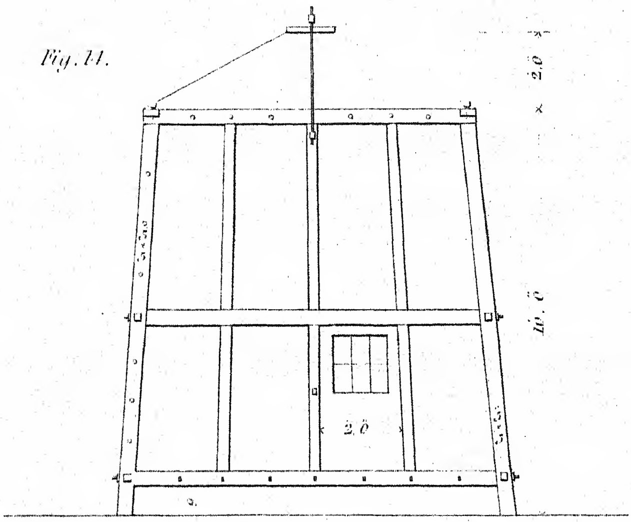
London, John Weale, High Holborn 1849.

PORTABLE OBSERVATORY.

North and South Sides of Zenith Sector.

ELEVATION.

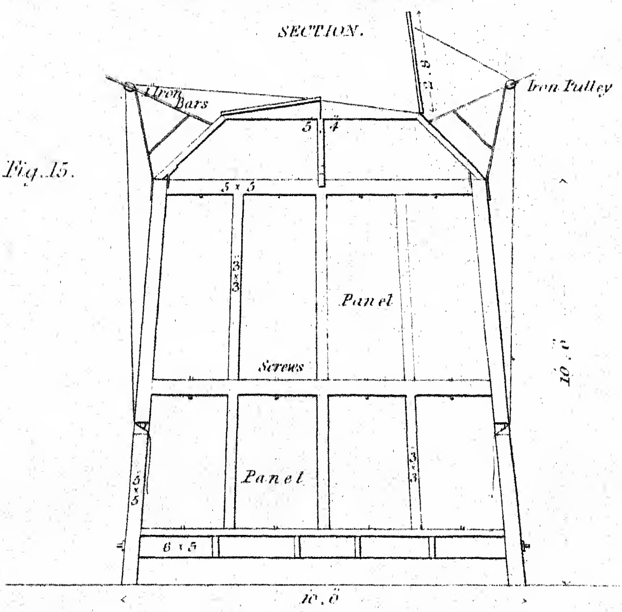
Fig. 14.



North and South of Zenith Sector.

SECTION.

Fig. 15.



Scale of Feet

10 5 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 ft

J. W. Lowry fc.

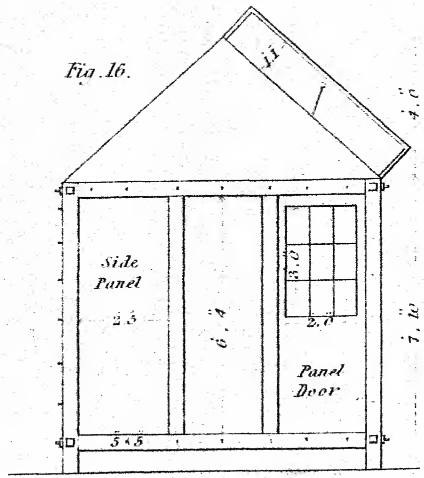
London, John Weale, High Holborn, 1849.

PORTABLE OBSERVATORY FOR A TRANSIT INSTRUMENT.

END ELEVATION

Roof Door Raised

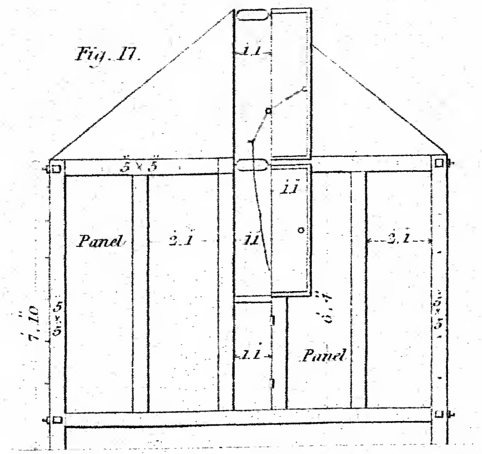
Fig. 16.



ELEVATION OF NORTH AND SOUTH

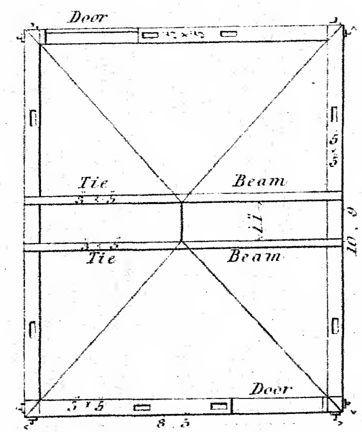
with Roof Door & Side Door open.

Fig. 17.



PLAN

Fig. 18.



Scale of Feet

12 6 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 ft.

J. W. Lowry fc.

London, John Weale, High Holborn, 1849.

OBSERVATORY, MAGNETICAL.*—Terrestrial Magnetism is the power which, acting upon a magnetic needle freely suspended by its centre of gravity, causes it to take up a certain position, called the magnetic direction, and also to tend to return to the same position if by any means it is withdrawn from that direction.

The direction of the needle is referred to two planes, the horizontal plane passing through the centre of the needle, and the vertical plane passing through the centre of the needle and the meridian of the place. The angle formed with the horizontal plane is called the inclination or dip, and that with the vertical plane, the declination or variation of the needle. As the magnetic direction and likewise the magnetic force vary at different parts of the earth's surface, it is necessary, in order to obtain a knowledge of the distribution of terrestrial magnetism, to ascertain for various geographical positions—

1st, The direction of the needle;

2ndly, The force by which the needle is retained in that direction; and

3rdly, The laws which govern the changes which take place both in direction and force.

The determination of the absolute values of the magnetic elements may be made at any station, independently of the co-operation of observers elsewhere: when a sufficient number of such observations shall have been made, (a work of some considerable magnitude,) charts might be constructed, shewing the values of the declination, inclination, and intensity over the surface of the globe; but even then the demands of the practical navigator, still more of the theoretical inquirer, would be far from satisfied: it would be found, that at the same spot the magnetic elements are subject to irregular fluctuations, the laws in respect to which are wholly unknown, and that on repeating the absolute observations after a lapse of time, the mean values themselves had undergone considerable change, whereby the whole aspect of the magnetical phenomena, correctly delineated at one epoch of time, had become entirely altered. To endeavour to obtain a knowledge of the laws by which these irregular fluctuations and regular secular changes are governed, as well as their connection with meteorological phenomena, besides other purposes which need not be here more fully alluded to, a laborious and continued system of observation was necessary to be made at geographical positions selected chiefly for magnetical considerations; and accordingly a certain number of observatories were established at stations of primary importance. The British Government undertook the cost of four of these observatories in different parts of our colonial possessions, viz. Canada, St. Helena, the Cape of Good Hope, and Van Dieman's Island; and the first three having been placed under the Ordnance department, a staff of observers for them was chosen from among the Officers and non-commissioned officers of the Royal Artillery: the observatory at Van Dieman's Island was intrusted to the care of Officers of the Royal Navy.

Plates III. & IV.

We may now proceed to give a brief account of the instruments with which these observatories were supplied, and of the instructions relative to the observations required to be made with them. As the observatories were furnished in all respects alike, and the system of observation was not only completely identical, but at simultaneous times, whatever may be related of one will apply with equal truth to the proceedings of all. The instruments used were,

Plates I. & II.

1. *A Declinometer*, for observing the regular daily, and irregular fluctuations, as well as for periodic changes.

This instrument consists of a magnet bar freely suspended by fibres of untwisted

* By Captain C. W. Younghusband, Royal Artillery.

silk, and furnished either with a lens and scale attached to the magnet, or with a mirror reflecting the scale at a distance. A telescope directed through the lens to the scale, in the first instance, or to the mirror which reflects the scale, in the second, enables changes of very small amount to be at once noted.

2. *The Bifilar Magnetometer.*—As no method has yet been rendered practicable for observing in one operation the changes of the total intensity of the earth's force acting in the direction of the dip, the total force is resolved into two other forces, one acting in the horizontal plane and the other in the vertical plane. The bifilar magnetometer was designed for the purpose of measuring the changes of that part of the force which acts in the horizontal plane, and consists of a magnet bar kept at right angles to the magnetic meridian, suspended by a double thread of silver wire, passing round a grooved wheel at its lower extremity, and between the threads of a screw at its upper extremity, the diameter of the wheel and the interval between the threads of the screw being accurately known, so that the two wires may be exactly equidistant throughout their whole length. Wheels of various sizes are supplied with each instrument, to be used as the station value of the horizontal force may require; it being necessary to employ a wheel of such dimensions that the torsion force caused by the twisting of the threads may exceed the magnetic force tending to draw the bar towards the meridian; yet not so much so as to impair the requisite sensibility of the instrument. The principle of the adjustment is briefly this. After having selected a wheel of suitable diameter, and suspended the magnet, turn the torsion circle any number of degrees (less than 180°) until the mean position of the magnet shall be exactly 90° from its original or natural position in the meridian. Now, were the suspended bar unmagnetic, the torsion circle would require to be turned only 90° to effect this object; but being magnetic, and having a constant tendency to return towards the magnetic meridian, the torsion circle requires to be moved more than 90°, and until the magnet assumes a position exactly at right angles to the magnetic meridian, in equilibrium between the force of torsion and the magnetic force. It is evident then, that supposing the magnetism of the bar itself to remain unvarying, an increase in the horizontal force of the earth's magnetism will be shewn by the magnetic force partially overcoming the torsion force, and the bar approaching the magnetic meridian; or, on the other hand, a decrease in the horizontal force of the earth's magnetism by the torsion force overpowering the magnetic force, and the bar being drawn still more than 90° from its natural position.

3. The changes in the vertical component of the earth's magnetic force are observed by means of a *Balance*, or *Vertical Force Magnetometer*, the magnet resting on agate planes by knife edges which pass through its centre of gravity. Were the needle unmagnetized, it would become horizontal on the agates, being truly balanced on the knife edges passing through the centre; but being a magnetic needle, it assumes a position of its own—that of the line of the dip. The upper end is then weighted until the mechanical force overcomes the magnetic force, and the needle becomes horizontal. It is then in equilibrium between two forces, the magnetic force urging it into the line of the dip, but counterbalanced by the weight applied to the other extremity: then, the magnetism of the needle being supposed to remain constant (as in the instrument last described), an increase in the vertical force of the earth will be shewn by the tendency of the needle to approach the line of the dip, and a decrease of the vertical force by the weight more than counterbalancing the magnetic force, and the weighted end sinking below the horizontal line.

In the two last instruments it will have been remarked that the unchanging magnetism of the needle is essential to the correct determination of the earth's changes of force. Observations, as usually made, contain the changes of both mixed

together, and it is necessary to eliminate the changes due to the varying magnetism of the bar before the true changes of the earth can be deduced.

Magnet bars are occasionally liable to undergo a gradual diminution of force; the effect of which it is necessary to take into account where a series of observations extending over a lengthened period of time requires to be reduced; but for short intervals, as from hour to hour, or day to day, the magnetism of the needle may be supposed stationary from this cause, and no correction applied. But there is another cause of change in the bar's magnetism, which on no account can be neglected,—that arising from a variation in the temperature of the metal since the previous observation was made.

The amount by which the magnetism of a needle varies by a change of temperature is not the same for all, but must be determined by experiment for every separate magnet; the process of experiment being simply this. The magnet whose *co-efficient of temperature* is to be determined is placed in a trough, and made to deflect another magnet freely suspended; water of various temperatures is poured into the trough, and the amount of deflection at each temperature noted. There will then have been observed a certain change in the effect produced upon the suspended magnet for a certain change in the temperature of the magnet under examination; from which data, by a simple process of calculation, the co-efficient of the magnet is obtained.

4. Since the first establishment of the Ordnance Magnetical Observatories a new mode of determining the changes of the vertical component of the magnetic force has been devised by Dr. Lloyd, and is now generally employed, though not to the entire exclusion of the original instrument, the Balance Magnetometer, which in some instances has been quite successful. The principle of the balance magnetometer is unexceptionable in theory, but its construction requires an amount of mechanical skill rarely attained: the accuracy of the results with some of the instruments of this kind has not consequently been as great as was expected, or indeed commensurate with that of the two magnetometers, for measuring the changes of declination and of horizontal intensity; the difficulty consisting in the very great proportion which the errors introduced by imperfection of workmanship in the axle of the needle may bear to the whole magnetic force; and thus the most minute disturbance of the relative parts of the instrument, or the smallest irregularities in the bearing points of the axle, affect the accuracy of the observations in a very appreciable manner. It was therefore desirable that some mode for observing the vertical component should be employed, which should not involve the principles of the balance. Dr. Lloyd devised an instrument for this purpose, which he called the *Induction Inclinometer:* it consists of a magnet suspended horizontally, acted upon by one or more soft iron bars held vertically in its vicinity. The iron bars should be, as nearly as can be obtained, devoid of permanent magnetic polarity: when held vertically, they will become temporary magnets under the inducing action of the earth, the lower extremities (in stations of northern dip) being north poles, and the upper extremities south poles: accordingly, if one be placed upon each side of the suspended magnet, and adjusted in such a manner that the horizontal plane passing through the centre of the magnet shall likewise pass through the upper end of one iron bar and the lower end of the other, the magnet will be acted upon by a north pole on one side and by a south pole on the other, and under their combined effect will be deflected a certain amount; the deflecting force being that of the vertical component of the earth acting by induction on the iron bars, while the opposing force is that of the horizontal component acting directly upon the magnet to bring it back into the magnetic meridian. Thus the magnet will take up a position of equilibrium between these two

forces, and a movement from its mean position, from which the effect due to any changes of horizontal intensity has been eliminated, will be that which is due to the change of the vertical intensity of the earth's magnetic force. A variation of temperature has a slight effect upon the induced magnetism of these soft iron bars, but in a much smaller degree than upon the permanent magnetism of hardened steel magnets. The co-efficient of temperature for the bars of each instrument must, however, be experimentally determined, the process being conducted in the following manner.

Surround the iron bars with water-tight cylindrical cases, made of wood or copper, soldered on to the arms which hold the bars, in such a way that they appear in the centre of each case, with space enough around them to enable the cases to contain a sufficient quantity of water to preserve an equable moderate temperature for a short time.

Adjust the instrument as for observation in the usual manner; fill both cylinders, first with warm water and then with cold; the two temperatures being the extremes to which the bars may be liable when required for observation.

At each alternation note the reading of the magnet scale and of the thermometer, when it will be found that the change of a certain number of degrees of temperature of the bars produces a certain amount of change in the magnetometer reading.

The induction inclinometer concludes the list of *differential* magnetical instruments required for the equipment of an observatory: their use, as will have been remarked, is that of shewing continuously the *changes* which occur in each element. Instruments of a different description are necessary for determining the *absolute* values of the same elements.

For the absolute declination, a magnetometer essentially unlike the differential apparatus is not required; as, supposing the magnet in the latter to be provided with an attached lens and scale, in the prolongation of which a theodolite is placed, the angle observed between the reading of the horizontal circle of the theodolite, when referred to the scale of the magnet and to a distant object whose bearing with the astronomical meridian is known, corrected for the difference between the *zero point* of the magnetic scale and the point at that moment on the vertical wire of the telescope, will be the absolute declination. The *zero point* is the point of the scale corresponding to the magnetic axis of the needle, and is a mean of two readings found by observing the magnet, first in its direct or usual position, and secondly in that position inverted: provision is made for accomplishing this in the construction of the instrument.

The other absolute determinations required are those of the magnetic force and of the direction in which the force acts. No method has yet been devised for determining the absolute total force by one operation; the usual mode being to observe, 1st, the angle of inclination of the needle, or the direction of the force; and, 2ndly, its horizontal component: then the horizontal force, multiplied by the *secant* of the inclination, will be equal to the total force; or, multiplied by the *tangent* of the inclination, equal to the vertical force. At stations of high magnetic latitude a very small error in the determinations of the inclination will occasion great error in the deduced value of the total force, for the secants of angles of an amount approaching 90° increase in a very rapid ratio; so that in extreme cases this method of obtaining the total force becomes quite inapplicable.

Dr. Lloyd has lately suggested an instrument for determining the total force in high latitudes in which the angle of inclination is not included as an element of calculation, the relative accuracy of whose results increases indefinitely as the inclination of 90° is approached: this method is consequently to be preferred where the

angle of inclination is of large amount; but in ordinary instances the total force will be better obtained by a determination of the horizontal component and of the inclination.

The *dip*, or angle of inclination, is determined by means of an instrument called an *Inclinometer*, which consists of a divided circle fixed vertically upon a horizontal circle moveable upon the axis of the base: the needle, whose length equals the diameter of the vertical circle, is suspended upon two agate planes by axles which pass through the centre of gravity, and are perpendicular to the faces of the needle: the needle, when unmagnetized, will then, if truly balanced, traverse round the circle, and remain in any position which may be desired. The mode of observation is as follows: the instrument being correctly levelled, magnetize the needle by passing two bar magnets, held one in each hand (the north pole of one and the south pole of the other downwards) over each face, beginning from the centre and drawing them over the ends; repeat this about 10 times, and the needle will have acquired sufficient magnetism,—that end over which the north pole of the bar magnet was drawn having become a south pole, and *vice versâ*. Place the needle thus magnetized on the agate supports, and turn the horizontal circle until it hangs vertically; the face of the instrument will by this means be brought into the plane perpendicular to the magnetic meridian of the station. Having read the vernier of the horizontal circle, move it 90°, to bring the face of the instrument to coincide with the plane of the meridian; the position of the needle, when at rest, will then indicate the dip or inclination. As the vertical circle may not have been truly divided, it is necessary to observe the reading of the needle with the face of the instrument turned both to the east and west; and as the magnetic axis of the needle may not coincide with the axis of form, it is necessary to place the needle with each face alternately directed towards the observer. Lastly, as the centre of gravity may not coincide with the centre of motion, it is necessary to reverse the poles of the needle by magnetizing it afresh, but making what has been hitherto a south pole the north pole, and the north a south pole: a mean of all the eight observations will be the inclination sought.

We now come to the determination of the *horizontal intensity*, the principle of which may be thus explained. If a magnetic needle be suspended horizontally, and allowed to vibrate, the square of the time of one oscillation, as compared with the square of the time of the same, observed under similar circumstances at another station, is in the inverse proportion of the horizontal intensity of the first station to that of the second: it is manifest, then, that the relative proportion of the horizontal intensity at any number of stations may be obtained by vibrating the same needle at each. These observations are, however, *only* relative, and dependent upon the individual properties of the magnet itself; or, in other words, the result will be an expression in which the *horizontal force of the earth* is combined with the *magnetism of the needle*. If we then can ascertain the ratio that one of these bears to the other, we shall have two equations in which each is an unknown quantity capable of elimination, and consequently the horizontal force of the earth may be determined in absolute measure. The ratio just spoken of is found by using the magnet employed in the vibrations, to deflect a second magnet suspended in another magnetometer, and observing the amount of deflection produced; then, one-half of the cube of the distance at which the centre of the deflecting magnet is placed, multiplied by the sine * of the angle of deflection, is to unity, as the magnetic moment of the deflecting magnet is to the horizontal force of the earth; which is the ratio required. By the

* When the two magnets are placed at right angles *to each other*, the sines are employed; but when the deflecting magnet is kept at right angles to the *meridian*, the tangents are taken.

experiments of vibration we obtain the product of the needle's magnetic moment and the horizontal intensity; and by the experiments of the deflection we obtain the ratio of the same quantities, from which either may be eliminated separately.

By the employment of the instruments now mentioned, an observatory will be fully equipped for determining each magnetic element in absolute measure, and for observing the periodic and secular changes over any space of time it may be wished to keep the instruments in use.

Besides these magnetical instruments, the colonial observatories were furnished with a complete set of Meteorological Instruments, comprising Standard and Mountain Barometers, Standard, Wet and Dry, Solar and Terrestrial Radiation Thermometers, Hygrometers, Anemometers, and Rain-Gauges. The indications of these, as well as remarks upon the weather, are registered at stated periods, in conjunction with the magnetical observations.

We have already remarked the fact, that the direction of the magnetic force and its intensity vary as the observer changes his geographical position; and also that these themselves, at any particular station, are liable to changes, whether secular, as from year to year, periodic, as depending upon the time of year or the hour of the day, or irregular, from extraneous causes known or unknown; and, firstly, we proceed to notice the changes found in the magnetic elements by an observer altering his geographical position, or, in other words, the representation of the distribution of magnetism over the surface of the earth.

The distribution of the earth's magnetism is represented by means of maps or charts containing systems of curves drawn through all the points where the value of each element respectively is of equal amount: thus, a map of the magnetic declination will represent a series of curves drawn through all the points where the declination or variation is equal: these are called *isogonic* lines, or lines of equal declination. A map of the magnetic inclination will represent curves drawn through all the points where the inclination or dip is equal: these are called *isoclinal* lines, or lines of equal inclination. And, in like manner, a map of the magnetic intensity will represent curves drawn through all the points where the intensity is of equal amount: these are called *isodynamic* lines, or lines of equal intensity.

The magnetic direction, as has been already stated, must be resolved into two elements,—the deviation from the astronomical meridian, measured on a horizontal plane, and the angle which the needle forms with the horizon, measured on a vertical plane.

The deviation from the astronomical meridian (latterly called the 'declination,' but more generally known as the 'variation of the compass,') is the element which, from its practical use, has naturally excited the greatest general attention. It is not necessary here to enter into the history of the discoveries of the properties of the magnetic needle: suffice it to say, that the knowledge that the needle did not point truly north,—secondly, that the deviation from the north was not the same in different localities,—and, thirdly, that the deviations, whatsoever they might be, were liable to continual change,—are all of recent date, compared with the discovery of the magnet itself.

The first attempt to form a variation chart was made by Alonzo de Santa Cruz, in 1530.* One hundred and fifty years later, Dr. Halley's theory of magnetism engaged so much attention, that a ship was granted him to seek by observation the variation of the compass in different parts of the world. He performed two voyages, one in 1698 and the other in 1699, and succeeded in obtaining so many valuable observations, that, on his return, he was enabled to construct a chart shewing the course of the curves of equal variation, 0°, 5°, 10°, &c. This work excited great interest,

* 'Cosmos,' vol. II. 282.

from being the result of personal observation; and it was the first that had yet been given to the world which could lay any claim to completeness or accuracy. It soon, however, became of little use for practical purposes, on account of the changes the declination was constantly undergoing; and half a century later, another chart was constructed from the records of various Naval Officers: this lasted until about the year 1787, when a chart constructed by Hansteen was published. Barlow published another in 1833. Since that apparently recent period, increased acquaintance with magnetism has suggested great improvements in the construction of instruments, which have been so actively employed in making observations, that the country is now in possession of ample data for the formation of correct magnetic charts of the greater part of the ocean. These, when completed, will bear a value much beyond any of those that have hitherto appeared, from being based upon direct observation alone, apart from theory, and with the employment of instruments incomparably superior to those of older construction, and also because the results have been calculated, having regard to certain corrections the importance of which has only recently become apparent, viz. such as arise from the effect of the ship's iron.

The great work of forming these magnetic charts has been commenced by the recent publication of Declination Charts of that portion of the globe covered by the Atlantic Ocean: these, together with an accompanying memoir, form the ninth number of Sabine's 'Contributions to Terrestrial Magnetism,' and are published in the 'Philosophical Transactions' of 1849. The curves are drawn for every degree of declination, upon the basis of the most recent observations, and are reduced to the epoch of January 1, 1840; a general table is added of the declination at the intersection of every 5th degree in latitude and longitude, from which may be calculated the value of the declination for any intermediate geographical position. In order to reduce the observation to any specified epoch, a second table contains the secular change per annum for each similar intersection in latitude and longitude, from which the correction is applied by simple addition or subtraction to the declination given for January, 1840.

It must not now be imagined that, with the possession of the charts and the tables for reducing the declination to a future epoch, this subject is disposed of, and will never require further consideration: such is far from being the case. In the first place, observations several times repeated in the same locality are necessary to determine the amount of the secular change, when constant; but it is well known that in many stations the secular change is not constant; and in such cases observations will require to be frequently repeated from time to time at these stations, to be used in the construction of new tables of the secular change per annum; and further, we have reason to hope that future observations will bear a higher intrinsic value than many that have been necessarily made use of in the charts now published: these observations, when made, will afford valuable verification of the normal values here employed.

A declination chart, however, includes but one element for a perfect representation of the magnetic phenomena: projections of the inclination and intensity are equally essential, together with tables by which we may be enabled to assign, with some degree of approximation, the values for either a former or future period. The completion of the Declination Charts of the Atlantic is one great step in contribution; but it is evident that there is still an extensive field for the labours of those interested in the knowledge of the laws of the distribution of terrestrial magnetism.

Of late years a thorough investigation into the laws of magnetism has been attempted, in which scientific men of all nations have employed themselves. The colonial observatories established by the British Government have already been alluded to: besides these, there are, in connection with Great Britain, a magnetical observatory at Greenwich, under the direction of the Astronomer Royal; one at

Dublin, established and conducted at the expense of the University of Trinity college, under the superintendence of Professor Lloyd; and the Makerstown observatory at Kelso, in Scotland, supported at the private cost of General Sir Thomas Makdougall Brisbane, Bart.; the magnetic observatories at Madras, Singapore, Simla, and Trevandrum, at the expense of the East India Company; at St. Petersburg, Catherinenbourg, Barnaoul, Nertchinsk, Sitka, and Tiflis, supported by the Russian Government, which, ever alive in the cause of science, has also furnished the Russian mission at Pekin with magnetical instruments; observatories at Gottingen, Milan, Munich, Prague, &c.

In addition to the fixed observatories, expeditions, sometimes specially undertaken for magnetical observations, sometimes in conjunction with hydrographical surveys or exploring parties, chiefly commanded by Officers of the British Navy, have been extended over almost every part of the globe, however remote or difficult of access. Some of these have returned, and the observations made by them published; many are still absent. Among the former class may be named the antarctic expedition of 1839–1843, under the command of Sir James Clark Ross; the expedition of Lieut. Moore, R. N., and Lieut. Clerk, R. A., in high southern latitudes, in 1845; Lieut. Moore, R. N., to Hudson's Bay, &c. Among the latter class are Sir John Franklin's arctic expedition, Captain Killett's survey in the Pacific, and Captain Stanley's on the Australian coast.

From these sources our knowledge of the existing phenomena of the earth's magnetism may be expected to receive considerable increase, and possibly may lead to some elucidation of the physical causes which produce the phenomena, whether their origin be sought for in the mass of the earth itself, being the resulting action of all its magnetized particles, or, as has been conjectured, that the phenomena are due to electric causes on the earth's surface, produced by the sun, the " source of all living activity."

Though science has failed to throw any light upon the causes to which the magnetical phenomena owe their existence, observation has very generally borne out one at least of the theories proposed by the many philosophers who have made magnetism their study, respecting the laws of the distribution of the phenomena. It is to our eminent countryman Halley that we owe the suggestion, first propounded in 1683, of the existence of four governing centres of magnetic intensity. So little credence appears, however, to have been given to this hypothesis, it is stated,* that up to " the commencement of the present century, the bare fact of there being any difference whatsoever in the intensity of the magnetic force at different parts of the earth's surface was unattested by a single published observation." Some years later, M. Hansteen undertook to examine the magnetical observations that had been made in regions of high latitude, and concluded " that Dr. Halley was the first person to discover the true magnetic arrangement of the globe, and that his deductions were fully as precise as the observations made in his time permitted." M. Hansteen proceeded to collect all the magnetic observations that had been made from the earliest periods. His tables extended to the year 1817; and after subjecting them to a close examination, he was enabled to prove the existence of a centre or focus of maximum intensity in the north of America; of a second centre, though not so powerful, in the north of Siberia; and of two corresponding foci, of unequal forces, in the southern hemisphere: he was also enabled to assign approximately the geographical position of each. That the data were insufficient for the more correct determinations of their positions, may be inferred from the remarkable fact, that at this time no observations had been made nearer the Siberian pole, than Berlin on the one side, and Mexico on the other.† Theory having thus pointed to the field requiring the labours of the

* Sabine on Magnetic Intensity. † Idem.

experimentalist, subsequent observation has with some exactness shewn not only the localities of these four foci or centres of intensity, but the relative numbers expressing at each the force of the magnetic attraction. The stronger focus of intensity in the northern hemisphere has been deduced, from observations made in 1843–1844 by Captain Lefroy, of the Royal Artillery, to be in 52° N. lat. and 92° W. long.; its value is 14·2: the weaker focus was determined by MM. Hansteen, Erman, and Due, to be in the north of Siberia, and about 120° E. long., with a value of 13·3. The stronger focus of intensity in the southern hemisphere is shewn to be in lat. 60° 19′ and long. 131° 20′, from observations made by Sir James Clark Ross, during his late expedition in the southern seas, and to have an approximate value of 15·6; while observations during the same expedition render it probable that the value at the weaker focus is 14·9 nearly, the higher values in the southern hemisphere being probably owing to the fact that these foci are closer together than the two in the northern hemisphere; though observation is still wanting to enable their position to be assigned very accurately. Now, the position of the four centres of intensity being known, and the amount of the magnetic force at each determined, and considering the positions and forces as data from which the magnetic phenomena at other parts of the globe may be assigned, it is interesting to examine how far the theoretical phenomena calculated on this hypothesis accord with the general facts made known by observation.

In proceeding to notice the magnetic distribution, our attention was first directed to the phenomena of the declination. Let us, however, leave this element for a while, and consider in the first place the *intensity* of the forces: the reason for so doing will presently appear. If it be supposed that, instead of the magnetic foci occupying the positions above mentioned, they were exactly at the same distance apart, each from each, and that every one had an equal value; isodynamic lines, or lines of equal intensity, of less force, would form circles described about each focus as a centre, and decreasing in value until the systems of circles intersect, because the amount of the force exerted by any three of them would be the same at all points equidistant from the fourth: also, if there were but two centres, though of unequal degrees of force, provided they were placed 180° apart measured on a great circle, the isodynamical lines described about each would still be circles. But as in reality there are *four* foci, all represented by unequal degrees of force, and at unequal distances from each other, the resulting action of the forces at any three centres causes the isodynamic lines to be found of the form of irregular curves about the fourth. As the centres in the southern hemisphere are probably at too great a distance to have but a slight, if any, disturbing effect upon the curves in the vicinity of the centres in the northern hemisphere, and *vice versâ*, those curves should become ovals, having their longer axes directed towards the adjacent centre,—that centre alone practically exercising a disturbing influence in causing the curves to deviate from circles. By observation, such is actually found to be the case; the maps of isodynamic lines, drawn from observations distributed over a great part of the earth's surface, accord in all their leading features with those derived from theory; and there is little difficulty in conceiving that the fact of the existence of four points or foci of maximum intensity being once established, and the position as well as the amount of the forces acting at each ascertained with some degree of certainty, that the calculated isodynamic curves should coincide generally with the configuration of the curves found by actual observation.

It is evident that, starting from each focus of maximum intensity considered as a centre, the intensity is of smaller amount, in whatever direction we may proceed: if we then draw lines through all the points in which the intensity is equal, we form curves which are ovals surrounding each other, that which represents a less degree of intensity enclosing within it all those which are of greater amount: systems of

curves are thus formed about four foci situated at certain positions on the globe. Continuing to draw these curves, the systems gradually approach each other, until at last two adjoining systems become actually in contact: the line then drawn through the points of equal intensity will represent the figure 8; and if we still continue to draw curves, the two systems will become one, lines corresponding to lower intensities enclosing both centres. The systems that first come in contact are the two northern together and the two southern together; so that there are then but two systems, one about the northern foci and the other about the southern foci. Continuing still to draw curves, these two systems themselves eventually encounter, and when in contact, a more extended figure of 8 is formed.

We have now evidently reached the limit beyond which no closed curve of equal intensity round any of the centres can be drawn; but keeping in view that the curves are projected on the surface of a globe, we find that a space exists not traversed by any lines, and where the intensity is of smaller amount than we have yet noticed: this space opens in some localities to from 10° to 20° of latitude, and at one place contracts to a point, the point of junction of the northern and southern systems: commencing from this point of junction, and drawing a line through the minimum intensity on each geographical meridian, there will be formed a line *separating the governing forces of the northern foci from the governing forces of the southern.* This line "is not one of those which has been characterized or referred to by M. de Humboldt, but is an important one in the view which it enables us to take of the magnetical relations of the different portions of the globe:"* the intensity on this line is of unequal amount; at the point of junction the intensity is greatest, and at a point on the meridian where the northern and southern systems are the farthest distances apart, the intensity is least, and represents the minimum of force on the surface of the globe.

The forces acting at these foci govern likewise the phenomena of the magnetic declination and inclination, causing the *isogonic* and *isoclinal lines* to follow certain curves; and it probably can be demonstrated that the calculated curves differ in no remarkable feature from such as are drawn from observation; but it is a matter of much greater difficulty to comprehend the nature of the laws which produce these curves (the isogonic and isoclinal) than of the forces necessary to produce the isodynamic curves; for this reason, that the isodynamic curves are purely magnetical, while the isogonic and isoclinal curves are expressed in reference to considerations having no necessary connection with magnetism. We cannot make this point more clear than by quoting at length the following remarks, extracted from Sabine's work on Magnetic Intensity.

"Viewed under the most favourable circumstances, and in its simplest aspect, the magnetism of the earth is still, it must be acknowledged, a highly complicated subject, and needs not the additional complication of its phenomena being involved with considerations foreign to itself. Now the lines of equal dip and equal variation do not express simple magnetic relations. The lines of equal dip, for example, connect those stations on the earth's surface where the direction of the magnetic attraction forms a certain angle with the horizontal plane at the station. But every station has its own horizontal plane, depending on the *direction of gravity*, which has no known or necessary connection with magnetism. The zero planes thus differing, the equality of dip does not express or necessarily imply a simple magnetic relation, but has reference to the attraction of gravitation, as well as to that of magnetism. The lines of equal variation express a complex relation of a similar character. Here, also, the zero planes change with the station; and, the variation being the same at

* 'Cosmos,' vol. i. p. 413, note by the editor.

two stations, by no means implies parallelism in the direction of the needle at them, or any other specific relation whatsoever, independent of the geographical pole, which pole has no known or necessary connection with magnetism. It is not the same with the lines of equal intensity. Whatever may be the sources of magnetic attraction, and wherever their situation in space,—whether superficial, as regards the earth, or above or beneath its surface,—the line of equal intensity expresses the equality of their resultant at all those points of the earth's surface through which it is drawn, unmixed with any considerations foreign to magnetism. They are pure magnetical isodynamic lines at the surface of the globe, and express a common relationship to the sources of magnetical attraction. The instruction they convey is therefore more simple, direct, and unequivocal than in the case of the other two. The eye of the mathematician may discern the pure magnetic indication through the complex signification of the lines of equal variation and dip; but the lines of intensity are better suited to convey the system of magnetism as indicated by the phenomena to the general apprehension."

The course of the *isogonic* lines presents some prominent features, the most remarkable of which are their general convergence towards the centres of maximum intensity in the northern and southern hemispheres; within a short distance of these points will therefore be found variations of great amount, both in the easterly and westerly directions.

The course of a line on which there is no variation is found to traverse the space between the two northern centres where the tendency of the magnetic needle to the eastward, under the influence of one centre, is exactly counterbalanced by the tendency of the needle to the westward, under the influence of the other. A similar line, along the whole of which there is no variation, is found between the two southern centres, following a course where the needle is in like manner governed by the influence of one southern centre exactly counterbalancing the influence of the other. But perhaps the feature most capable of arresting attention in examining a chart of variation, is the existence of two ovals or curves of equal declination whose extremities meet and form closed systems: one of them is situated in the Pacific Ocean, and the other in Eastern Asia.

The general aspect of the projection of the *isoclinal* curves conveys the impression of a greater simplicity in the action of the forces by which they are produced, than in the forces which govern the isogonic and isodynamic curves.

The line of no dip, or the line drawn through all those points where the needle remains horizontal, and the inclination consequently equal to 0, encircles the globe near the terrestrial equator. From this line the inclination gradually increases as a higher latitude is attained, whether in proceeding northward or southward, until the vicinity of either pole be reached, when the needle becomes vertical, or the dip is 90°.

The above very brief description is sufficient to give a general idea of the course of the isoclinal lines, and is, in fact, but a very rough approximation to the truth, as we shall find upon entering into a more detailed examination of the question. It appears, from observations made by Captain Duperrey, of the French Navy,—who undertook a voyage of circumnavigation in the years 1822–1825, by order of his Government, for the purpose of making magnetical observations, and more particularly with the design of ascertaining the precise localities at which the needle remained horizontal, —that the line of no dip at that time crossed the equator in long. 5° E. (from Greenwich), and proceeding southward, attained its extreme southern limit in 15½° S. lat. and in long. 39° W.: turning from thence again towards the north, it reached within 2½° of the equator in 100° W. long., having on the way effected a slight retrograde movement near the western coast of South America: proceeding thence in almost a

parallel line with the equator, but inclining slightly northward, it arrived in N. lat. in the meridian of 180°; continuing thence so rapidly to the northward, that it was found to have made 7½° of lat. in traversing 37° of long. eastward; and following the same parallel of latitude until the meridian of 120° was attained, northing was again gradually made, until the maximum distance from the equator of 13½° was reached, in 4 ° E. long. Turning from this point to the southward, the line proceeded uninterruptedly to its starting point on the equator, in 5° E. longitude.

If we start from the line of no dip, and travel directly northwards, the *north* end of the needle is found to incline below the horizontal line, and to dip more and more as we proceed: if we travel southwards from the same line, the *south* end of the needle becomes the lower, and continues to incline in like manner in our progress; but the increase of the angle of inclination, in low latitudes especially, more than keeps pace with the increase of the latitude. Humboldt, on one occasion, found a change of inclination amounting to 8° 1′, corresponding to a difference of 3° 57′ of lat.; and upon another, a change of inclination of 20° 7′, produced by a difference of 9° 50′ of latitude. While such is the case, a ship's position may often be known from a determination of the inclination, when an astronomical observation could not be obtained; in fact, the magnetical observation might often be found not only the most simple, but the most useful, from its results being available at any time of the day or night. Instances are on record where the magnetical observation has actually been applied to this purpose.

Sir J. C. Ross observed the needle to be vertical, the north end dipping 90°, on the 2nd June, 1831, in lat. 70° 5′ N., long. 96° 46′ W.* The same Officer observed a south inclination of 87° 05′ in lat. 74° 59′ S. and long. 173° 40′ E., the greatest inclination of the south end of the needle that has yet been observed. From his observation it has been inferred that the needle would be vertical in about 74° S. lat. and 150° E. longitude.

It has occurred to us here to remark, for the purpose of preventing the possibility of mistake, that wherever in this paper the North end or pole of the magnet is spoken of, it is to be understood that we refer to that end which points towards the North, and of the South end that which points towards the South. It is necessary that a clear understanding on this point should exist, because many writers employ these terms precisely reversed, calling the North end of the needle that end which is directed towards the South, and *vice versâ*, stating as a reason, that because the north pole of a magnet repels the north pole and attracts the south pole of another, that is, as there exists a repulsion between powers of the same name, and attraction between powers of the opposite name, they consider that the earth, the most powerful of all magnets, should be supposed to exert a similar effect upon magnets influenced by it, and therefore that end of the needle attracted towards the North pole of the earth should be called the *South* end, and that end repelled from the North pole and attracted towards the South pole, should be called the *North* end of the needle. We have, however, employed the terms most generally in use, as more obvious and less likely to cause confusion.

Having now completed a general view of the distribution of magnetic elements over the globe, we may proceed to notice the changes to which these elements are liable.

The secular change is that change by which an element at any particular station is found to increase or diminish from year to year, sometimes reaching a certain limit, and then slowly returning to the original value. This, no doubt, is due to the movement of the governing centres of intensity; but the direction and rate of that motion, and whether all or any of them make the circuit of the globe, are questions not yet

* 'Philosophical Transactions,' Part I. for 1834.

capable of correct solution. The effect of the secular change is, in the course of a series of years, so to alter the earth's magnetic distribution, that the existing maps exhibiting graphically the course of the curves no longer convey correct representations of the phenomena, and consequently render it necessary to resort to observation again for the construction of new maps. For this purpose, Humboldt says, "it would be requisite to send, four times in each century, an expedition of three ships, which should have to examine, as nearly as possible at the same time, the state of magnetism over all the accessible parts of the globe which are covered by the ocean."

The next order of changes are the regular diurnal fluctuations.

Mr. Graham, a celebrated mathematical instrument-maker in London, is said to have discovered, in 1722, that the northern extremity of the needle moved westward during the early part of the day, and returned again eastward in the evening to the same position which it occupied in the morning, remaining nearly stationary through the night.

The observations at the Colonial Magnetical Observatories having been made at the commencement of every hour throughout the twenty-four, the nature and amount of the diurnal movement at those stations has been determined with considerable accuracy; and it has been found, that not only the declination is effected by a regular diurnal march, but also that the magnetic intensity of the earth is subject to regular diurnal changes, as shewn by the variation of the magnets in the horizontal and vertical force magnetometers. The observations made at Toronto in Canada shew that at that station the north end of the needle attains its extreme westerly limit between 1 and 2 o'clock in the afternoon; that it moves to the eastward until between 9 and 10 at night, returning again westerly until about 2 A.M., from which time, until 8 A.M., it proceeds steadily eastward, when its limit is reached in that direction: from 8 A.M., until the early part of the afternoon, the progression is rapidly and steadily westward. The same observations shew that these movements are somewhat modified by the season of the year; that during the summer months the extreme limits take place rather later, both in the morning and afternoon, and that the range is considerably greater; the amount of the diurnal variation being from 10′ to 12′ during the summer months, and not more than from 5′ to 7′ during the winter months; the movement in the spring and autumn bearing an intermediate character.

The curve of daily variation will probably be found to possess the same general character at all stations in the middle latitudes of the northern hemisphere. The Greenwich observations, taken two-hourly, shew that the western limit is attained extremely regularly at 2 P.M., but that the eastern limit is more generally found at the hour at which the second minimum is reached at Toronto, viz. about 10 P.M.; though frequently, and more particularly during the summer months, the extreme eastern limit is attained at the morning hour, 8 A.M. The Greenwich observations also exhibit the double movement, having two maxima and two minima.

In the middle latitudes of the southern hemisphere, the hours of local time corresponding to each turning point seem to be as nearly as possible identical with the turning points in the northern hemisphere; that is, comparing the daily movements of a declination magnet situated in the northern hemisphere with the daily movements of another magnet at a station in nearly similar latitude in the southern hemisphere, and situated on the same meridian, there is found to be a remarkable connection between the movements of the two magnets, the extreme positions and the secondary maxima and minima being attained at nearly simultaneous times; but the directions of the movements are precisely contrary: while the north end of the magnet is progressing westwardly in the northern hemisphere, the north end is moving eastwardly in the southern hemisphere, and *vice versâ.* The peculiar connection between the diurnal curves in the northern and southern hemispheres is further exemplified

in the effect of season: the characteristic feature of the summer curve in the northern hemisphere, as has been already stated, is that the diurnal changes are much greater than in the winter months; and this we find to be the case in the southern hemisphere, the greater diurnal movement taking place during the southern summer months.

If we consider the contrariety of movements simultaneously occurring in the northern and southern hemispheres, we perceive it to be clearly impossible that two observers approaching the equator in opposite directions should find that the western movement of the north end of the needle is suddenly converted into an eastern movement, and an eastern into a western movement, and that therefore the conjecture was by no means unreasonable, that as the observers approached each other, the diurnal changes would be found gradually to diminish, both ceasing altogether in a space or zone where, the two movements being neutralized, the needle remained stationary. M. Arago arrived at this conclusion, expressed in the following words: "il y a nécessairement entre la zone où s'observe le premier de ces mouvements et celle où s'opère le second, une ligne où, le matin, l'aiguille ne marche ni à l'orient ni à l'occident, c'est-à-dire reste stationnaire." Humboldt recently alludes to the same problem, and appears to consider the existence of a zone or line round the earth, answering these conditions, highly probable. The question has, however, been solved, and in a manner, perhaps, scarcely anticipated.

Sabine has shewn, in a paper read before the Royal Society, February 18, 1847,* that there are certain stations, which may be regarded as situated between the northern and southern magnetic hemispheres, where the diurnal variation possesses the characteristics of the phenomena of both. While the sun is in the northern signs, the movement of the north end of the needle corresponds in direction to what we have mentioned as taking place in northern latitudes; and while the sun is in the southern signs, as to what we have mentioned as occurring in southern latitudes. This conclusion was arrived at from the examination of the results of the observations at the Observatory at St. Helena, situated in 15° 57′ S. latitude, and where the inclination is about 22°. The fact is very decidedly proved, that in November, December, January, and February, the diurnal variation corresponds to that observed at Toronto in Canada, as an instance of the diurnal variation in the northern magnetic hemisphere; while in May, June, July, and August, the variation is similar to that observed at Hobart Town, Van Dieman's Island, considered as exemplifying the diurnal variation in the southern magnetic hemisphere; also, that in March and April, September and October, the months when the sun is in the vicinity of the equator, the movements partake more or less of the characteristics of both seasons: a detailed examination of this subject will be found in the paper already alluded to, and we without hesitation arrive at the conclusion that a line or zone characterized by the disappearance of all diurnal variation does not exist on the globe.

This interesting peculiarity in the diurnal curve of the declination, as well as the general employment of the instrument for practical purposes, has induced us to refer particularly to its changes. It may be sufficient to notice, with respect to the indications of the other instruments, that the force undergoes a certain change depending upon the hour of the day, forming each day a certain curve in an extremely regular manner; and we dismiss the consideration of these changes with the remark, which applies to all regular movements, that the occurrence of irregular changes are sufficient so frequently to destroy, or rather to mask the regular march of the needle, that a series of observations must be prolonged to some considerable extent, to arrive at any precise conclusions regarding the character of the curves. This has now been accomplished at the Colonial Observatories.

* Phil. Trans. Part I. for 1847.

Our attention may next be directed to the irregular fluctuations, phenomena which are calculated to excite the greatest interest. These magnetic disturbances, when of any considerable amount, seem always to be accompanied by the Aurora, and both the disturbances and Aurora apparently to be excited by the same cause.

It has been the custom at the Ordnance Magnetical Observatories, upon an irregularity in the march of the needle manifesting itself, to commence continuous observations, and not to abandon them until the disturbances cease and the magnets return to the position due to the period of the day: as the regular observations are made hourly, the commencement of a disturbance can scarcely fail to attract immediate notice. Upon inspecting a table of disturbances, it is impossible to avoid at once perceiving that they appear to have been observed on the same date at several, or all of the stations, a great number of times. From such a list, now before us, it does not appear that a single disturbance of tolerable magnitude occurred at any one of the observatories, but that the magnets at all the others were observed to be in a similar state of perturbation; nor can the idea be resisted that the exciting cause, whatever it may be, is so general as to affect the magnetism at all parts of the globe at the same time. April 14th, 15th, and July 1st, 2nd, 3rd, and 4th, 1842; May 6th, 1843; April 16th, 17th, and October 20th, 1844, all days of much disturbance, taken almost at random from such a general table as that before mentioned, are instances of the exciting cause manifesting itself at stations widely scattered over the globe, and essentially unlike in geographical and climatological relations.

The interest that is attached to the phenomena of simultaneous disturbance, and the hope that a thorough investigation into their effects may conduce to some knowledge of causes, render it particularly desirable that no period attended with a disturbance in the equilibrium of the magnetic forces should occur without an accompanying register of the needle's excursions.

So long as the establishment of an observatory is on a sufficiently extensive scale to permit a system of observation to be sustained, similar to such as has been in operation at the Colonial Observatories, a pretty constant watch can be kept upon the magnets, and any irregular fluctuations scarcely fails to be noticed: the omission does not, at all events, extend beyond the hour at which the next regular observation is registered; and even that would be avoided, could an apparatus be contrived which should act as an alarum when the excursion of the magnet exceeded by a certain amount the usual diurnal variation: but when the disturbance has once commenced, unless a number of observers be ready to contribute their assistance, the movements of the magnets cannot be followed uninterruptedly; and should the disturbance extend over a period of many hours, the most zealous observers must in the end be compelled by fatigue to relinquish their task. For this class of observations, a mode of automatic registration would appear to be especially valuable; and as it is not advisable to impede in the slightest degree the free motion of the magnet, by causing it to exert any mechanical force, however slight, the desired object seems likely to be effected by means of photography. Mr. Charles Brooke is the inventor of an apparatus which has been employed with great success at the Magnetical Observatory at Greenwich, in self-registering the movements of the magnets.

The method consists in attaching to the centre of the magnet a concave elliptical mirror, which receives, from a camphine light, a vertical pencil of light passed through a slit about one-fourth of an inch deep and one-hundredth of an inch wide in the copper chimney of the lamp. The mirror reflects this pencil through a cylindrical lens, the axis of which is horizontal, thereby reducing the vertical pencil of light to a point, and the point of light is received upon prepared paper wrapped round a cylinder which revolves horizontally on its axis by means of clock-work. The point of light

thus undergoes a horizontal movement corresponding to that of the magnet, but magnified proportionably as the distance of the cylinder from the mirror is increased; and the revolution of the cylinder causes each portion of the paper successively to be subject to the action of the point of light.

The chemical preparation of the paper, and the subsequent bringing out the curve traced, need not be here described. An account of the apparatus, illustrated by drawings, with fac-similes of some impressions obtained, is published in the 'Philosophical Transactions,' Part I. for 1847.*

An apparatus on a somewhat different principle, in which the use of the camphine lamp has never been found necessary, employing the sun's light by day and that of a common Argand lamp by night, is the beautiful invention of Mr. Francis Ronalds, of Kew. Mr. Ronalds's apparatus consists in suspending a very fine blackened wire vertically over or beyond the end of the magnet, passing through slits in the bottom of the case enclosing the magnet, and descending into a lucernal microscope beneath. Near to the wire, or index, as it is called, is the *object-end* of the microscope, closed by a pane of glass by day and by condensing lenses when the Argand lamp is used. Between the index and the other end, fine achromatic lenses are placed, which have the effect of condensing the light upon a small screen fixed at that end, and also of projecting upon it a strong image of the index. A very narrow slit is cut horizontally in the screen, and behind it is a frame containing the photographic paper, which is enclosed between two thin plates of glass: the frame is moved in a vertical direction by clock-work. The clock being now started, every portion of the paper is carried successively past the slit, and exposed to the action of strong light; the index, however, interposes itself, and throws a shadow, reduced to a point by the horizontal slit, on the paper as it is drawn upwards. This shadow traces a curve, following exactly every movement of the magnet.

We have been desirous of limiting our notice of the important subject before us to a mere outline of its several branches, and of the modes of observation by which our knowledge of them continues to increase, and have endeavoured carefully to avoid being drawn into details, of which if each point received its due share we should have found the space allotted us in the present volume far from sufficient, as well as occasioning an inconsistency in the character of the publication. We are anxious, however, before concluding, to draw attention as briefly as possible to the study of magnetism chiefly in respect to the practical advantages attendant upon our increasing knowledge of the science, amounting to the supplying a hitherto much felt deficiency.

Many are disposed to regard magnetism in the light alone of an interesting study in abstract science; and though we are far from estimating the value of the study of pure science by its direct and visible bearing upon increased prosperity, believing it to be the never-failing means of exalting the intellect and purifying the mind, and that an adequate return for scientific researches is to be found in a higher standard of intellectual cultivation, yet the direct application of abstract investigations, though unperceived, is no less eventually certain; and we have evidence in the rapid advancement in manufactures and the arts, in our comforts and the every-day occurrences of life, of the practical application of purely scientific labours which in themselves were viewed as but profitless occupation, standing apart from worldly welfare, and inter-

* Since the above was written, Mr. Brooke has been able, by increasing the sensibility of the prepared paper, to cause a good impression to be produced by the action of naphthalized gas: gas is laid on at the Royal Observatory, Greenwich, which being passed through a vessel containing naphtha, is employed in the photographic registration of all the magnetometers. From still more recent experiments made at his house in London, Mr. Brooke entertains confident hope of so preparing the paper, that the action of a common oil lamp, notwithstanding the loss of light occasioned by reflection, may be sufficient to produce a distinct trace of the magnetic movements.

esting only to the speculative philosopher. But if we consider our subject in its practical and visible uses alone, we shall find proofs sufficient of the eminent real benefits to be attained by a more competent knowledge of magnetism. It is to the magnetic needle we are indebted for the safe guidance of our ships, as well in the ordinary navigation of the ocean as in the discovery of distant countries, ever the sailor's faithful friend, whether clouds and fog obscure the sun by day, or veil the stars by night. Yet our position with regard to the science may be truly described to be an imperfect knowledge of the magnetic distribution of the globe, or of the laws which govern its ever-varying phenomena, and a total ignorance of causes. Of late years much has been done to lay the basis, at all events, of a much augmented knowledge, and the subject has engrossed a degree of attention which it seems unaccountable to have delayed so long.

The principal practical use of the magnetic needle is, obviously, in the navigation of ships when out of sight of land; but that true dependence may be felt in its correct guidance, to enable known dangers to be avoided, and to inspire confidence that the ship is being truly steered to its destined port, we must not only possess a knowledge of the earth's magnetism, but we should take care to place in the hands of our seamen instruments really efficient, and above all, to secure the intelligent employment of them.

The compass, more perhaps than any thing else in the ship, is generally, as it ought to be, the object of the sailor's most jealous care; but it rarely happens that its construction is of such delicacy as is commensurate with the results expected from its guidance, or that there is shewn sufficient acquaintance with its nature and properties; so that in fact the compass, in such cases, loses much of the value otherwise its due.

The cause which most frequently operates to impair the efficiency of the ship's compass, is the not ascertaining and allowing for the aggregate influence upon it of the ship's fixed iron, and from not observing due care in keeping moveable portions of iron-work from its vicinity. Several remarkable instances in which, owing to want of precautions of this kind, the most lamentable accidents resulted, are quoted by Captain Johnson, R. N., in a very useful book published lately, entitled 'Practical Illustrations of the Necessity for Ascertaining the Deviation of the Compass.'

The comparative rudeness of construction of ship's compasses generally in use until within a very short period, and the before-mentioned causes rendering them in a still greater degree unsafe guides, were some time since urged upon the serious consideration of Government, and resulted in the appointment by the Admiralty of a Committee, who were directed to examine into the state of the compasses in the present employment of Her Majesty's Navy, and to suggest such improvements in their construction, and directions for their use, as would insure the proper application of a correct instrument to the purposes of Navigation.

The result of this inquiry has been, that in addition to the binnacle compasses, each ship of war is now ordered to be furnished with an instrument of very improved construction, called the 'Standard Compass,' and fixed upon a permanent support or pillar near the midship line of the ship, at a sufficient height above the deck to permit bearings being observed. Directions have also been given, that before going to sea, every ship should be swung with her head successively upon each of the thirty-two points, and the deviation of the standard compass needle, or error from the magnetic north, caused by the iron of the ship, determined for each point; which deviation should be subsequently allowed for when laying down the course: these observations are to be repeated when the ship shall have changed considerably her geographical position. The ship's course is intended to be invariably directed by the standard compass, and the corresponding bearing of the binnacle compass regarded solely as an approximate guide to the helmsman. Finally, an Observatory has been built, and placed under the control of Captain Johnson, whose duty it is to examine

all compasses previously to being employed, to superintend the swinging of the ships, and to see that the Officers in charge possess correct tables of the deviations.

APPENDIX.

*Memorandum on the Books to be kept at the Magnetic Observatories.**

The books which will be required for registering the magnetic observations are—

1. A Day-Book.—2. A Term-Day Book.—3. A Miscellaneous Register.—4. An Abstract Book.—5. A Book for Curves.

1. The Day-Book.—The instruments required to be observed daily at the regular magnetic hours are, the three magnetometers, the thermometers of the horizontal and vertical force instruments, the barometer with its attached thermometer, the dry and wet bulb thermometers, and the electrometer, in all ten (10) in number: an observation with Daniell's hygrometer of the temperature of the dew-point will be taken four times daily, one at each of the magnetic hours nearest to the times 3 and 9 A. M. and P. M. of the reckoning in mean time at the observatory: the state of the weather will also be generally described at the same periods as are assigned for the observation of Daniell's hygrometer: at the magnetic hours this record is left to the discretion of the observer: *regular* observations at these times are not required. The maximum and minimum of temperature and radiation will be noted once daily.

Form No. 1 is arranged to contain a complete series of daily observations in one open page: the left hand contains the register of the magnetometers, and the right-hand page the meteorological register: the headings of the several columns in the Form have been entered, and will render them sufficiently intelligible without further explanation. Three readings of the declination and horizontal force instruments will be taken at each observation, and the horizontal lines corresponding to the times of observation have consequently been ruled in triple sets: the first and third readings of each observation should be entered on the left side of the columns so designated, and on the first and third lines of the set, and the second or middle reading on the right hand and on the centre line. In the vertical force instrument only two readings are taken at each observation, viz. one of each end of the magnet; they may be entered on the first and third lines of the set. The means of all the observations should be entered on the middle line of the three.

As the three magnetometers cannot be observed simultaneously by the same person, it is to be considered as a general rule that they are to be observed in the order and at the times following, viz.

Vertical force magnetometer, 2m. 30s. before the hour.
Declination magnetometer, at the hour.
Horizontal force magnetometer, 2m. 30s. after the hour.

As it is intended that the series of daily observations shall comprise the whole of one civil day, according to the usual reckoning of time at each observatory, it will be necessary to make the first set of observations at the time nearest after midnight, corresponding to one of the magnetic hours of Gottingen mean time: thus, supposing the difference of longitude, in time, of one of the observatories to be 4h. 36m. 41s. (or 4h. 37m.†) east of Gottingen, the time at the observatory of the first daily observation (*a* in Form No. 1) would be 12h. 37m. P.M., or thirty-seven minutes after midnight, and would correspond to the magnetic hour 8 P. M. of the day previous at Gottingen (A in the Form). The other observations of the magnetometers will follow in regular order, and will be fourteen (14) in number, including that one taken at

* From 'Report of Royal Society,' 1840.

† The nearest whole minute may be taken in the daily observations, but greater exactness will be necessary on term-days.

2 P. M. Gottingen mean time, which is triple. These instruments will be registered for the triple observation as follows:

	1	2	3	4	5	6	7	8	9
H. M. S.	1:50:00	1:52:30	1:55:00	1:57:30	2:00:00	2:02:30	2:05:00	2:07:30	2:10:00
	V	D	H	V	D	H	V	D	H

Numbers have been entered in Form No. 1, corresponding to those in the above Table, which will point out the time of observation for each instrument, and also the order in which they follow. This arrangement has been adopted in the Form, to prevent the necessity of leaving blanks.

The height of the barometer, and of its attached thermometer, of the dry and wet bulb thermometers, the temperature of the dew-point, the electrometer, and the state of the weather, will be entered in their proper columns on the right-hand page, at every magnetic hour, but not at the other times of the triple observations. The maximum and minimum of temperature and radiation may be noted at the foot of the right-hand page, after the state of the weather.

2. TERM-DAY BOOK.—One day in each month has been set apart for simultaneous observations of the three magnetometers, at short intervals. The declination instrument will be observed every five (5) minutes, beginning with each complete hour; and the horizontal and vertical force instruments every ten (10) minutes, each one successively in the middle of the alternate intervals, between the observations of the declination magnetometer: one observation will thus be taken every 2m. 30s., which makes twenty-four during each hour, or 576 during the day. The five thermometers, the barometer, the electrometer, and the state of the weather, will be registered at the beginning of each hour only.

The Term observations will be registered according to Form No. 2, in which each page contains the observations made during one hour. An inspection of the first page of the Form, in which the headings have been inserted, will render the mode of entry familiar.

The first observation will be made at 10 P. M., Gottingen mean time, of the Wednesday or Friday appointed, for which the corresponding time (to the nearest *second*) at the observatory must be calculated, and entered on the first set of lines of its proper hour-column. The time at observatory for each succeeding observation should be entered in a similar way, and the whole of the times for each complete term-day, twenty-four pages of the Form, should be filled up previous to the commencement of the observations, that no uncertainty may exist as to the precise time at the observatory at which each observation will have to be taken.* The three magnetometers will be registered successively, one under the other, on the lines corresponding to their several times of observation, as shewn in the specification column of the Form: these lines have been ruled in sets of three, for the same reason as given in the Day-book.

The hourly observations of the thermometers, the barometers, electrometer, and the weather, will be registered in their proper columns at the foot of each page, where will also be entered the temperature of the dew-point, at the four six-hourly periods, and the maximum and minimum of temperature and radiation.

* It will be found advisable to have one of the chronometers set to Gottingen mean time, and if it have a *losing* rate it will be still more convenient, as the hands may then be moved *forward*, to the nearest minute of Gott. M. T. (an operation which does not affect its *rate*), whenever necessary.

3. Miscellaneous Register.—This book will contain the register of—

1. Absolute determinations;
2. Miscellaneous observations; and
3. Extraordinary observations.

The *absolute determinations*, which will be made *once every month*, are those of the dip, declination, and intensity of the earth's magnetism; the magnetic moment of the bars, and the fixity in position of the reading telescopes.

Miscellaneous observations are those made for the adjustment of the magnetic and astronomical instruments; of the changes in the adjustments; of the effects of temperature on the magnets; of the latitude and longitude of the observatory (which should be occasionally repeated, until its place shall have been determined with all the accuracy which the instruments employed will admit of); for determining the time, and rating the chronometers, &c.

Extraordinary observations are such as will be taken whenever an indication may be made, by the movements of the magnetometers, that causes are in operation which exercise a disturbing influence upon the needle. Any remarkable phenomenon,—as an Aurora, for instance, which is known to exercise such influence, occurring during such disturbed movements,—should, if noticed, be carefully recorded.

The magnetometers are also to be watched during storms of thunder or wind, or during the occurrence of any phenomenon which may be suspected or considered likely to influence the movements of the magnetic needle, and their effect, if any, ascertained by a series of observations, and registered. Where no effect is observed, the same will, nevertheless, be noted, and a memorandum made of the time through which the magnetometers were watched, with reference to the phenomenon, to ascertain the fact. When, however, after several repeated observations during the occurrence of any, the same kind of phenomenon, as storms of wind, for instance, it shall appear that the magnets remain undisturbed, such observations may be discontinued.

The above observations will be kept separately for each month, and should be so arranged that an easy reference may be made, when necessary, to any individual entry.

No particular form is necessary for the miscellaneous register, but it will be convenient to have it ruled with faint lines, as in Form No. 6.

4. Abstract Book.—A monthly abstract of the observations taken each day will be made, according to Forms Nos. 3, 4, 5, and 6, and of the Term observations according to Forms Nos. 7, 8, 9, and 6. Each of the instruments registered daily, at the twelve magnetic hours, will occupy for the whole month one page of the abstract, and they will follow each other in the order of the Day-book, the thermometers attached to instruments being registered on the same open page with them.

The corrected observations of the barometer will be reduced to the temperature 32° Fahr., and corrected for capillarity: this latter correction, however, on account of the size of the tubes, is very small.

The temperature of the dew-point, and the elasticity of vapour corresponding to it, (which may be deduced from Table No. 5 in the Report,) also the maximum and minimum of daily temperature and of solar and terrestrial radiation, and the monthly abstract of the daily triple observations, will be inserted in the three sets of columns ruled separately for each instrument; but the monthly means of these observations are not to be taken.

No observations are to be made on Sundays: the greatest number of working days, therefore, in one month, will not in any case exceed twenty-seven, for which extent the Form provides. The sums and means of the observations at each magnetic hour, for the whole month, will be entered in their proper hour-column at the foot of the page, on the horizontal line so designated.

All the observations taken on term-days, which correspond with the magnetic hours of the daily series, will be included in the abstract of the daily observations, as well as in the Term-day abstract.

The monthly absolute determinations, as also the miscellaneous and extraordinary observations, do not require to be inserted after any particular Form; and a blank sheet of ruled paper will be added to the Forms for each month, to insure space for their entry and for remarks.

The state of the weather as observed daily will admit only of being transcribed at length; it will be necessary to do this in the copies of the Monthly Abstract which are to be sent home, but not into the Abstract Book which remains at the observatory, as they are registered in detail in the Day-book.

The term-day observations will be abstracted agreeably to Forms Nos. 7, 8, 9, and 6, of which the first page is for the declination magnetometer, the second for the horizontal and vertical force instruments, page 3 for the hourly observations of the meteorological instruments, and page 4 for remarks.

The first page contains thirteen vertical columns, and is divided into two parts, each containing twelve horizontal lines: the first column is for the minutes of each hour in Gottingen mean time, at which the observations of the declination magnetometer are made, and the twelve following columns, which will contain the observations, are designated by the hours, in Gottingen mean time also, in order as they occur on the Term-Day Book. The upper half of the page contains the first twelve hours, and the lower half the last twelve hours of the twenty-four, commencing with 10 P.M. Gottingen M.T. of the day appointed in the programme. Each observation will be entered in the hour-column of that part of the page to which it belongs, and on the horizontal line designated by the minute of the hour which it was taken: thus an observation taken at the hour 6h. 45m. A.M. Gottingen M.T. would be entered in the *upper* part of the page on the 10th horizontal line, and in the 9th hour-column. Similarly an observation taken at 1h. 00m. P.M. would be entered on the 1st horizontal line and on the 4th hour-column of the *lower* part of the page: by this arrangement one column in each part of the page contains in abstract the observations of one page of the Term-Day Book.

The second page contains the abstract of both the horizontal and vertical force instruments, the observations of each of which are taken at double the interval of the declination instrument, *i.e.* every ten minutes; the former at 2m. 30s. 12m. 30s. &c., and the latter at 7m. 30s. 17m. 30s. &c. of each hour. The Form for both instruments is similar, and their designations differ only in the horizontal lines, which will be numbered as above in each Form, agreeably to the absolute times at which the observations of each instrument are made. The arrangement of the Forms is similar to that of the declination instrument, excepting that there are only six instead of twelve horizontal lines in each part for each instrument, corresponding with the number of observations per hour which will be taken, and that each part contains an extra line for abstracting the hourly observations of the thermometers of these instruments.

The method of entry is similar to that laid down for the declination magnetometer: the hourly observations of the thermometer will be entered on the horizontal line at the foot of each part, and in the hour-column to which it belongs, agreeably to the designation at the head of the part. One column of each part of these Forms contains, as above, the abstract of one page of the Term-Day Book.

The manner of abstracting and entering the meteorological instruments on Term-days will be sufficiently evident from an inspection of page 3 of the Form. The means of the observations will be taken every six hours, but their numbers being few, their sums will not be entered. The state of the weather at each magnetic hour will be

transcribed into the unoccupied portion of the page in those copies of the abstract which are to be sent home, but need not be entered in the Abstract Book which will remain in the observatory, having been registered in detail in the Term-Day Book. The temperature of the dew-point, at the four six-hourly periods, also the maximum and minimum of temperature and radiation, will be entered likewise, in the vacant part of this page. The fourth and last page, which is for remarks, is ruled simply with faint lines, according to Form No. 6.

5. CURVE BOOK.—The comparison of the results will be much facilitated by projecting them in curves; and for this purpose each observatory is furnished with a Curve Book, the pages of which are printed from an engraved plate.

A comparison of *individual* results is only required where it is desired to trace the progress and laws of the *irregular* changes. Such a comparison, accordingly, will always be made of the results of simultaneous observations on term-days. It may also be done when, on any extraordinary occasion, the progress of a disturbance has been watched at short intervals.

The mean results, contained in the Monthly Abstract, are,

1. The *daily means* of the results at the twelve *magnetic* hours, and
2. The *monthly means* corresponding to *each hour* separately:

the latter of these determine the law of the diurnal oscillations, the former that of the monthly change. It is desirable that the monthly results of each of these series should be projected in curves; but it will be necessary, beforehand, to apply the corrections for temperature, as explained in the Report. The instruments whose results it is desirable to record in this manner are, the three magnetometers, the barometer, the wet and dry thermometer, and the electrometer.

The Form, of which a specimen is annexed, consists of twelve principal and two quarter compartments in length, and six principal and two half-compartments in breadth. Each compartment, which is an inch each way, is divided into six principal divisions marked by strong lines, and these are again subdivided into two by faint lines, so that the inch is subdivided into twelve parts each way. This arrangement has been made to admit of the more easy projection of term-day curves, and because it is convenient in assigning the time value of the scale in the projection of curves generally.

The curves of the *monthly means* corresponding to *each magnetic hour* separately may be laid down on the breadth of the page, each half-compartment corresponding to the interval of the daily observations, or to *two hours;* each principal division, *i.e.* the interval between two strong lines, will represent one division of the scale in the declination and horizontal force instruments, the tenths of which will be *estimated* as they are in making the observations. For the vertical force magnetometer, one principal division of the Form will represent one division of the micrometer head, or five such divisions a whole turn of the screw. *Increasing easterly variation,* or an *increase of force,* will be represented by tracing the curve upwards, during the given intervals; and the converse for *decreasing* easterly variations, or for a *diminution* of force, *i.e.* by a descending curve. The point of commencement will be towards the *left,* and the intervals of time will be reckoned in regular succession to the *right.*

The *daily means* of the results at the twelve *magnetic hours* may be laid down across the page also, and in manner as above described, each principal division representing an interval of one day; increasing values being represented by an ascending, and decreasing ones by a descending curve.

The curves of the term-day observations will be projected along the length of the Form, each half-inch representing an interval of one hour of civil time: one subdivision will thus be equal to ten minutes, *i.e.* to two intervals of observation of the declination, and one each of the horizontal and vertical force magnetometers; the

values of the scale being taken as before directed. The curves will commence at the left hand, and be traced towards the right.

The curves of *irregular variations* will be laid down similarly with the above; but they may be projected on the breadth of the page.

The above books will form a complete record of the magnetic observations carried on at each observatory, and it would be desirable to have them collected in some one office, where access may be had alike to all, when the whole period through which they are to be taken shall have expired. With a view, however, of comparing the results obtained at each observatory, and for the purpose of publication, duplicate copies of the monthly abstracts, both of the daily and term observations, and of the register of the weather, both on ordinary and on term-days, will be required; and it is hoped that one copy, at least, of these documents will be despatched from the observatories regularly every month. Regarding the second copy, a particular arrangement will be entered into for their transmission, which will be communicated to the Superintendent of each observatory, for his information and guidance.

An Annual Report should also be furnished by the Superintendent of each observatory, noticing all occurrences which may appear worthy of special remark, giving a general history of the proceedings during the year, and stating the conclusions which, in his opinion, may be drawn from a comparison of the observations of one month with those of another. It will be interesting also to receive from each Officer, when the observatory under his superintendence shall be in regular course, a detail of the operations performed in making all the preliminary adjustments before commencing the series of observations with each instrument, and of the precautions taken to secure accuracy in their results.

FORMS OF THE BOOKS.

Note.—The letter a, at the head of the second column of Form No. 1, represents the time nearest after midnight, corresponding to some one of the magnetic hours of Gottingen mean time, and will always fall between midnight and 2 A. M. of mean time at the observatory. The letter A, on the same line in the first column, is that magnetic hour of Gott. M. T. with which a corresponds. The other letters in both series represent the consecutive magnetic hours, or intervals of two hours of civil time; the capitals in Gott. M. T. the small letters in M. T. at observatory. In the triple observation the letter H' represents 1 h. 50 m. P. M.; H stands for 2 P. M., and H'' for 2 h. 10 m. P. M. Gott. M. T.; and the letters h', h, and h'', represent the observatory times corresponding thereto.

The place of the triple observation will occur in different parts of the page at each observatory, according to the magnetic hour Gott. M. T., which may be there represented by the letter A. In the Form this is supposed to be midnight; *i. e.* the longitude of the observatory is assumed to be on the meridian of Gottingen, and, consequently, the times A and a are similar. The numbers 1, 2, 3, &c., inserted in the columns headed '*Readings*,' shew the order in which the magnetometers are to be read, and represent also the *times* of those readings as contained in the columns of the Table, page 3, headed by similar figures.

The small letters in the first column of page 2, at the head of the twelve columns in Form No. 3, denote the same times as the like letters in the second column of page 1, Form No. 1.

All the Forms which relate to the observations of ordinary days, and their abstracts, have been printed in Italics; and those relating to term-day observations, and their abstracts, in Roman type.

[Books and loose papers have been prepared agreeably to the above directions, and may be had of Mr. Weale, 59, High Holborn.]

FORM No. I.*

________day, the______of _________________18___. OBSERVATORY at (________________________)
Daily Observations of MAGNETOMETERS

	Gott. mean time.	Mean time at Obser-vatory.	Declination Magnetometer. Readings.	Declination Magnetometer. Mean.	Horizontal Force Magnetometer. Readings.	Horizontal Force Magnetometer. Mean.	Horizontal Force Magnetometer. Ther.	Vertical Force Magnetometer. Readings.	Vertical Force Magnetometer. Mean.	Vertical Force Magnetometer. Ther.
	A	*a*								
	B	*b*								
	C	*c*								
	D	*d*								
	E	*e*								
	F	*f*								
	G	*g*								
			2		3			1		
Triple Observation.	*H′*	*h′*								
			5		6			4		
Triple Observation.	*H*	*h*								
			8		9			7		
Triple Observation.	*H″*	*h″*								
	I	*i*								
	K	*k*								
	L	*l*								
	M	*m*								

* As the days commence with the magnetic hour nearest after 12 midnight *of the place*, the time of the triple observation will be different at each Observatory, and cannot therefore be printed.

FORM No. I.

OBSERVATORY at (________________) ________*day, the*____ *of*
and METEOROLOGICAL INSTRUMENTS. ____________________ 18______

Mean time at Observatory.	*Barometer.* Height.	*Barometer.* Temp. of merc.	*Thermometer.* Dry.	*Thermometer.* Wet.	*Electrometer.*	*Electrometer.*	*Temp. Dew-Point.*	
a								
b								
c								
d								
e								
f								
g								
h								
i								
k								
l								
m								

	State of the Weather.
a	*Note*
b	
c	
d	
e	
f	
g	
h	
i	
k	
l	
m	
9 *A.M.*	*Temperature Max.* ( ) *Min.* ( )
9 *A.M.*	*Radiation Sol.* ( ) *Terr.* ( )

FORM No. 2.

OBSERVATORY at (________________) __________ day, the _____ of
Term-day Observns. of MAGNETOMETERS, &c. ______________ 18 _____

Specification of Magnetometer.	Times of Observation.		Magnetometer.		Times of Observation.		Magnetometer.	
	Gott. M.T.	M.T. at Ob.	Readings.	Mean.	Gott. M.T.	M.T. at Ob.	Readings.	Mean.
	10 P M m. s.	m. s.			10 P M m. s.	m. s.		
Declination	0:00				30:00			
Horizontal Force	2:30				32:30			
Declination	5:00				35:00			
Vertical Force	7:30				37:30			
Declination	10:00				40:00			
Horizontal Force	12:30				42:30			
Declination	15:00				45:00			
Vertical Force	17:30				47:30			
Declination	20:00				50:00			
Horizontal Force	22:30				52:30			
Declination	25:00				55:00			
Vertical Force	27:30				57:30			

Hour of Gott. Mean Time.	Thermometers.				Barometer.		Electrometer.		
	H. F.	V. F.	Dry.	Wet.	Height.	Temper.			
10 P M									
	Weather.								

FORM No. 3.

OBSERVATORY at (________________)

Abstract of daily Observations made during the month of __________ 18 ____

Date.	*Name of Instrument.*												Sums.
	a	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*	*k*	*l*	*m*	
Sums													
Means													

FORM No. 4.

OBSERVATORY at (________________).

Abstract of daily Observations made during the month of ________ 18___

Date.	*Temperature of Dew-Point.*				*Elasticity of Vapour.*				*Temperature.*		*Radiation.*		*Moon's Age.*
	3 *AM.*	9 *AM.*	3 *PM.*	9 *PM.*	3 *AM.*	9 *AM.*	3 *PM.*	9 *PM.*	*Max.*	*Min.*	*Solar.*	*Terr.*	
Sums													
Means													

FORM No. 5.

OBSERVATORY at (______________)

Abstract of triple Observations made during the month of ________ 18___

Date.	*Vertical Force Magnetometer.*			*Declination Magnetometer.*			*Horizontal Force Magnetometer.*			
Sums										
Means										

The Sums and Means of the triple observations are not required; they have been included in this Form, of which a portion is blank to admit of the insertion, if necessary, of other observations in the same page.

FORM No. 6.

FORM No. 7.

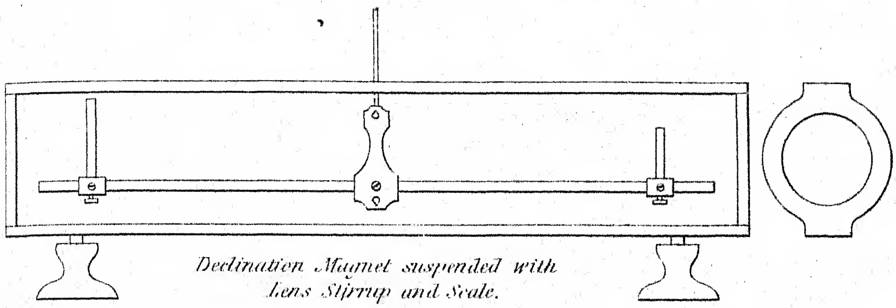
OBSERVATORY at (________________) _________ day, the _____ of
Abstract of Term-day Observations ____________________________ 18___

Gott. Mean Time.	Declination Magnetometer.											
	10 P M	11	Midn.	1 A M	2	3	4	5	6	7	8	9 A M
m. s. 0:00												
5:00												
10:00												
15:00												
20:00												
25:00												
30:00												
35:00												
40:00												
45:00												
50:00												
55:00												
	10 A M	11	Noon	1 P M	2	3	4	5	6	7	8	9 P M
m. s. 0:00												
5:00												
10:00												
15:00												
20:00												
25:00												
30:00												
35:00												
40:00												
45:00												
50:00												
55:00												

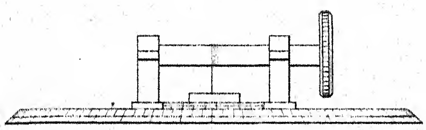
FORM No. 8.

OBSERVATORY at (————————) ———— day, the ——— of
Abstract of Term-day Observations ———————————— 18——

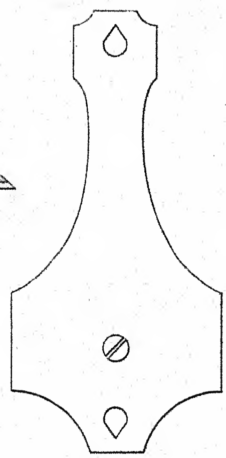
Gott. Mean Time.	Horizontal Force Magnetometer.											
	10 P M	11	Midn.	1 A M	2	3	4	5	6	7	8	9 A M
m. s. 2:30												
12:30												
22:30												
32:30												
42:30												
52:30												
Ther.												
	10 A M	11	Noon	1 P M	2	3	4	5	6	7	8	9 P M
2:30												
12:30												
22:30												
32:30												
42:30												
52:30												
Ther.												
	Vertical Force Magnetometer.											
	10 P M	11	Midn.	1 A M	2	3	4	5	6	7	8	9 A M
7:30												
17:30												
27:30												
37:30												
47:30												
57:30												
Ther.												
	10 A M	11	Noon	1 P M	2	3	4	5	6	7	8	9 P M
7:30												
17:30												
27:30												
37:30												
47:30												
57:30												
Ther.												

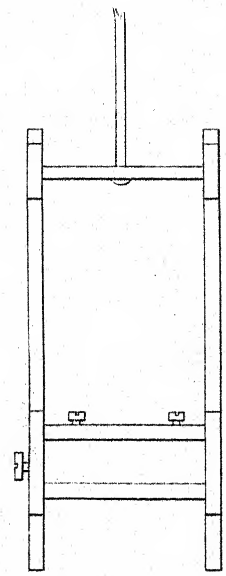


Declination Magnet suspended with Lens Stirrup and Scale.

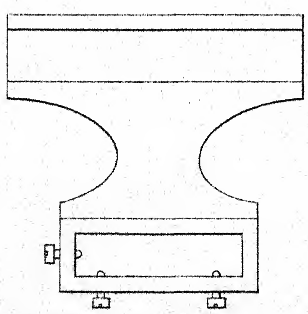


Suspension Apparatus and Torsion Cord of Declination Magnetometer

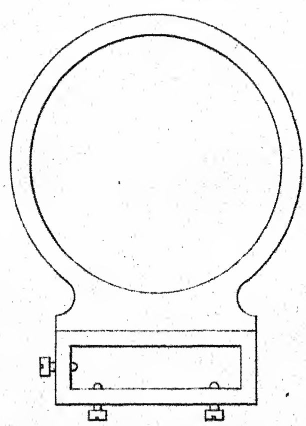




Front Elevation of Stirrup



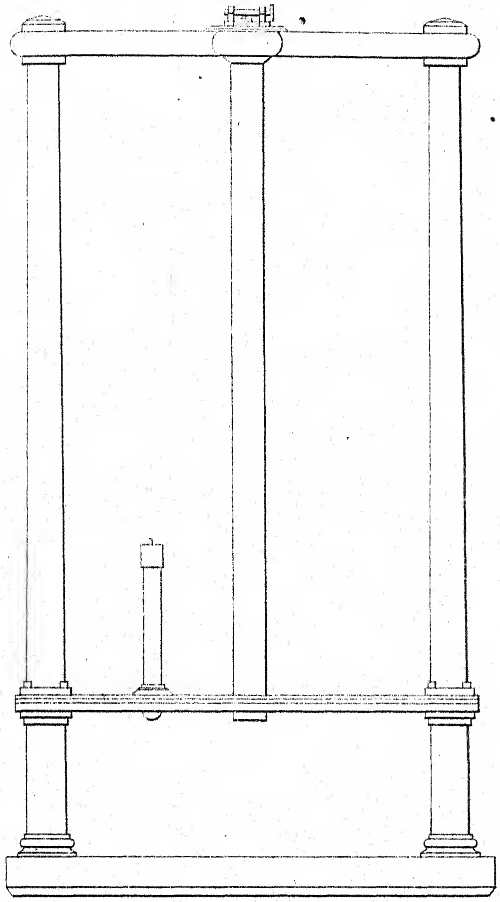
Front Elevation of Scale.



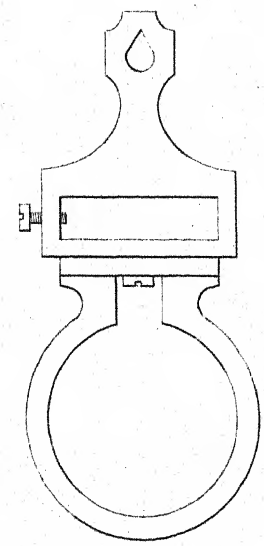
Front Elevation of Lens.

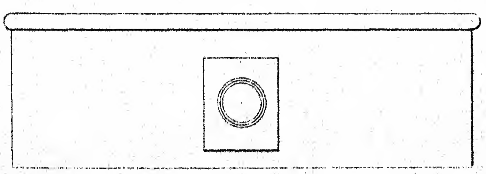
J.W. Lowry fc.

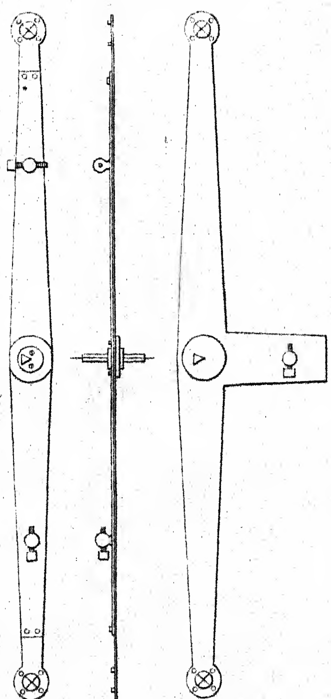
London; John Weale, 59, High Holborn, 1849.



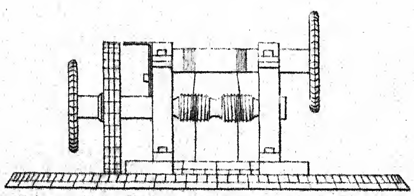
Frame work of Declination or Bifilar Magnetometer







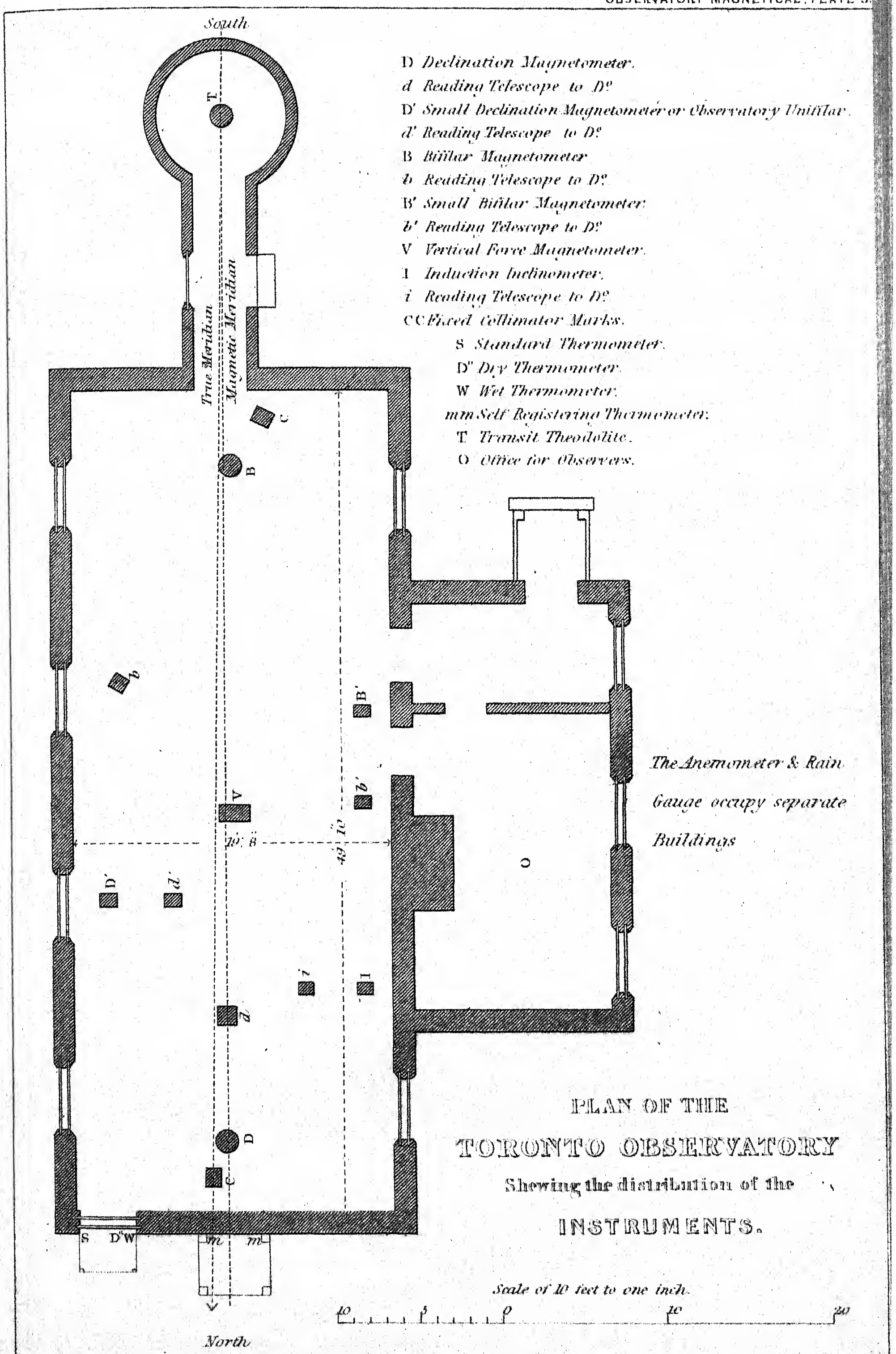
Vertical force needle.



Suspension Apparatus and Torsion Cord of Bifilar Magnetometer.

J.W. Lowry sc.

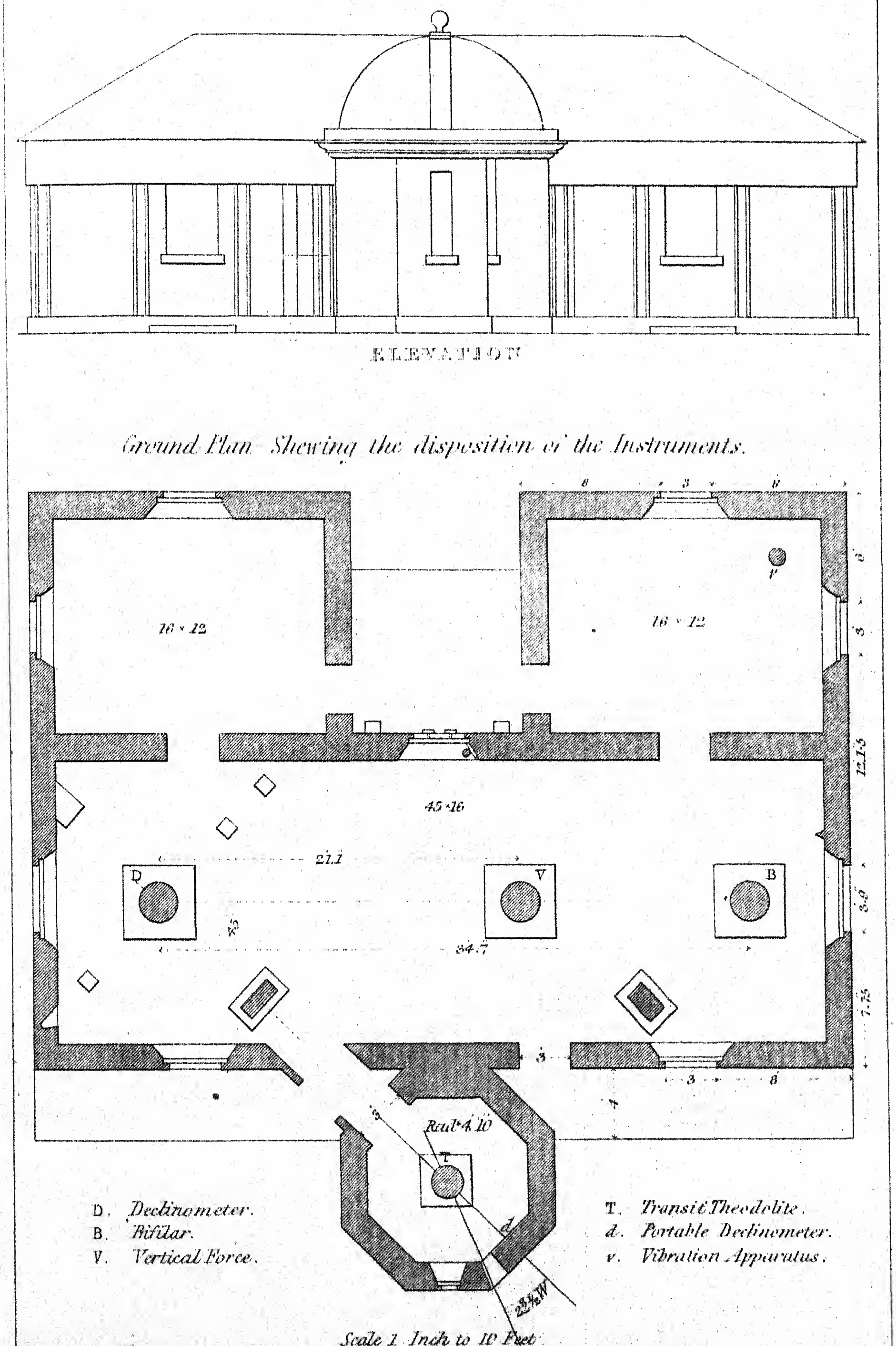
London, John Weale 59 High Holborn 1849.



J.W. Lowry fc.

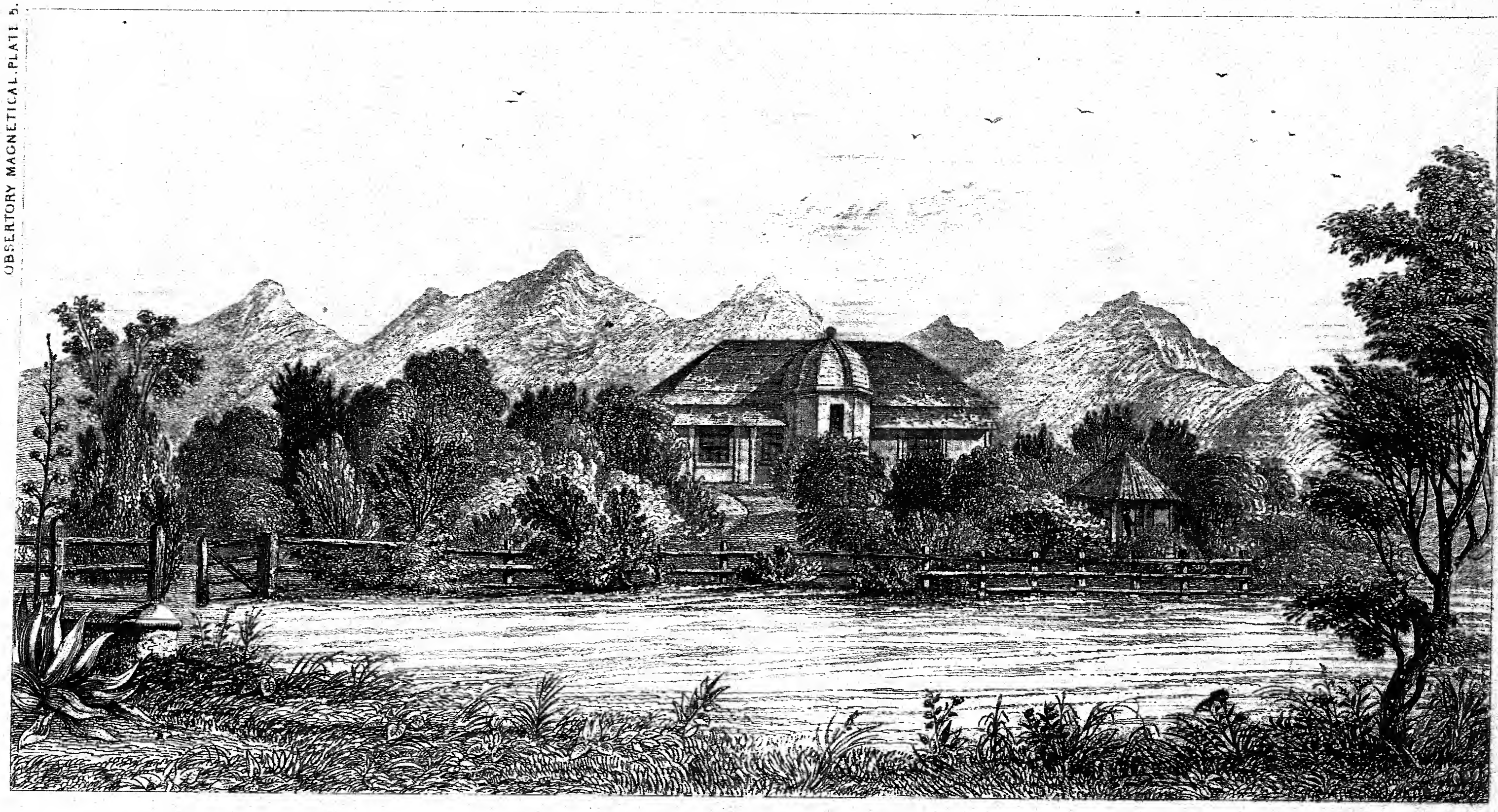
London, John Weale High Holborn 1850.

MAGNETICAL OBSERVATORY ST HELENA.



J.W. Lowry fc.

London John Weale High Holborn 1849.



J. W. Lowry fc.

Magnetical Observatory, St Helena

London, John Weale 59 High Holborn, 1849.

FORM No. 9.

OBSERVATORY at (———————) ——— day, the ——— of
Abstract of Term-day Observations ——————— 18——

Gott. Mean Time.	Barometer.		Thermometer.		Electrometer.		State of the Weather.
	Height.	Temp.	Dry.	Wet.	.		
10 P M							
11							
Midn.							
1 A M							
2							
3 A M							
Means							
4 A M							
5							
6							
7							
8							
9 A M							
Means							
10 A M							
11							
Noon							
1 P M							
2							
3 P M							
Means							
4 P M							
5							
6							
7							
8							
9 P M							
Means							

ORDNANCE, BRITISH.*—By the term Ordnance is understood, in the British Service, any description of warlike stores, whether for Land or Sea Service, and the Ordnance Department has the manufacture and conservation of these stores: this general application of the word is not the purport of the present article; it is the special signification used by the Artillery, comprehending every projectile fired from a carriage—forming a part of the equipment of that branch of the Military Service, (as explained in the first volume of this work in the article '*Artillery*,') and also a portion of the materiel, and termed Ordnance, as follows:

- Ordnance.
  - Iron
    - Guns,
    - Howitzers,
    - Mortars,
    - Carronades.
  - Brass
    - Field Guns,
    - Do. Howitzers,
    - Small Mortars.
  - Rocket
    - Heavy,
    - Field.

The first use of ordnance, and the progress of the several improvements, is here proposed to be recorded.

It is supposed that ordnance, or a species of cannon, was first employed by the English in the reign of Edward the Third, and that in 1346 he had four pieces at the battle of Cressy: at that time they were made of wrought-iron bars, welded together and strengthened with hoops; but their construction rendered them more mortars than cannon, as they had chambers. One of this description was taken by Oliver Cromwell at Edinburgh, called 'Mons. Meg.' Cannon of this description were also termed *Bombards*, but in time they were cast of that composition named gun-metal.

Although heavy ordnance was in use as early as the time of Edward III., none was cast in England until the reign of Henry VIII., when great brass ordnance was constructed, and called cannon, and culverins, cast, according to Camden, by one John Owen: in the year 1543, the latter Sovereign employed two foreigners to assist in the foundry; and at the close of this century bombs were cast to fire carcasses, fire-balls, and grenades.

At the beginning of the 17th century much attention was given to the casting of cannon in England, then designated as follows:

Cannon Royal,	carrying	48-℔. shot,	of	90	cwt.
Bastard cannon	,,	36	,,	70	,,
Half ditto	,,	24	,,	60	,,
Culverins	,,	18	,,	50	,,
Demi-culverins	,,	9	,,	38	,,
Falcon	,,	6	,,	25	,,

Some curious notices of ordnance are given in a work printed in the year 1637, by Henry Hexham, Quarter-Master to the regiment of the Hon. Colonel Goring. He states that the charges of gunpowder were equal to $\frac{3}{4}$ths of the weight of the shot, and that cannon and demi-cannon were employed for battering, but that field-pieces or *drakes* were for sudden service, as in the day of battle. The former were mounted

* By Colonel Cater, Royal Artillery.

on block-waggons, or upon their own carriages, and required fifteen couple of lusty horses, besides the '*thiller horse*,' every two horses drawing 600 or 650 lbs.: a demi-cannon required eleven horses, and the smaller drakes a number according to their weight. The rebouching of guns was first practised at that period.

The first improvement towards the present nature of ordnance took place in the middle of the 17th century; and in the reign of James II., A. D. 1686, it is recorded that orders were given to equip fourteen 3-pounders to act with several regiments of infantry encamped in Hyde Park, and two guns were attached to each battalion.

In the records alluded to is a Return of British Ordnance, dated 1669, when *cast-iron ordnance* appears to have been in use. The following Table is copied from the record:

GUNS.		MORTARS.	
Brass.	Iron.	Brass.	Iron.
Cannon of 8 in. calibre.	Cannon of 7 in. calibre.	$18\frac{1}{2}$ in. calibre.	$12\frac{1}{2}$ in. calibre.
„ 7 „	Demi-cannon	$13\frac{1}{4}$ „	$4\frac{3}{4}$ „
„ 29-pr.	Cannon 29-pr.	9 „	$4\frac{1}{4}$ „
„ 12 „	„ 12 „	$8\frac{1}{4}$ „	
„ 8 „	„ 8 „	6 „	
„ 6 „	„ 6 „	$4\frac{1}{2}$ „	
„ 3 „	„ 3 „	$4\frac{1}{4}$ „	

It may be inferred from the perusal of the 'Marlborough Dispatches,' edited by General Sir George Murray, that guns were not at that period attached to battalions. At the battle of Blenheim, it is stated, that when the Duke found that he could make no impression on the enemy, he directed Colonel Blood, of the British Artillery, to cross the river with a battery, over which a bridge had been formed; and this artillery manœuvre contributed materially to the success of the day.

It is stated likewise, in one of the Duke of Marlborough's dispatches, dated 26th September, 1704,—"On Wednesday there arrived before Landau twenty 24-pounders, twelve 12-pounders, eleven mortars, two howitzers, and one hundred hand-mortars; and we hope in a few days to have another battery of twenty-eight 24-pounders:" and at one time he says, "we shall require 10,000 horses."

The inferior quality of the gunpowder, the charges being $\frac{3}{4}$ths of the weight of the shot, (one-third being the present maximum charge used,) must have produced the necessity of such a large supply of ordnance in the field and at sieges.

About 1736, General Armstrong, then Surveyor-General of the Ordnance, took great pains to improve the construction of British ordnance; and, profiting by his experience under the Duke of Marlborough, established certain rules for the dimensions of iron and brass guns, based upon some experiments made under his direction. These rules were,—that for iron guns, supposing the calibre to be divided into 14 equal parts, he decided that the thickness of the metal at the vent should be 16 parts.

The thickness at the	first reinforce	14·5 parts.
„	second „	13·5 „
„	end of the second reinforce . .	12·5 „
„	beginning of the chase . . .	11·5 „
„	end of the muzzle	8 „

The diameter of the vent, $\frac{1}{4}$th part of an inch.

The diameters of brass guns were regulated by dividing the calibre into 16 equal parts, when the thickness of the metal at the breach was to be 16 parts.

At the end of the first reinforce	14·5 „
At the beginning of the second	13·5 „
At the end „	12·5 „
At the beginning of the chace	11·5 „
At the end „ , exclusive of mouldings,	8 „

Diameter of vent, $\frac{1}{5}$th of an inch.

The length of the guns, according to General Armstrong's construction was, fo–

BRASS.	Ft.	In.	IRON.	Ft.	In.
32-pr.	10	0	32-pr.	9	5
24 „	9	5	24 „	9	0
18 „	9	0	18 „	9	0
12 „	9	0	12 „	8	0
6 „	8	0	9 „	7	0
3 „	7	0	6 „	6	6
1½ „	6	0	3 „	4	6

fired with a charge of two-thirds of the weight of the shot; shewing that the manufacture of the gunpowder had not at that time improved. It is assumed that the brass ordnance was for the field, and that the iron was employed in the armament of forts and ships of war.

Brigades of artillery were organized, of 12-pounders and light 6-pounders, to accompany the Duke of Cumberland in his campaign in the North of England, in 1747. This must have been the first attempt at light artillery, with certain facilities of movement without embarrassing that of the infantry.

At the battle of Minden, 1759, where the British artillery particularly distinguished itself, there were five brigades employed, composed of medium 12-pounders, light 6-pounders, and howitzers; and at the siege of Belleisle, in 1761, there were employed six 12-prs., twenty 24-prs., ten 32-prs., and several heavy mortars and 8-inch howitzers.

In 1764, when the Marquis of Granby was Master-General of the Ordnance, the following weight and dimensions were established for British ordnance:

BRASS GUNS.		Length. Ft.	In.	Weight. Cwt.	Qrs.	Calibre of Gun. Inches.	Calibre of Shot. Inches.
Heavy	42-pr.	9	6	61	0	7· 3	6·68
	24 „	9	0	52	0	5·83	5·54
	12 „	9	0	29	0	4·63	4·48
	9 „	9	0	26	0	4·21	4·0
	6 „	8	0	19	0	3·66	3·40
Medium	24 „	8	0	42	0	5·83	5·54
	12 „	6	6	21	0	4·63	4·48
	4 „	5	0	10	0	3·66	3·40
Light	24 „	6	6	16	0	5·83	5·54
	12 „	5	0	8	3	4·63	4·43
	6 „	4	6	4	3	3·66	3·40
	3 „	3	6	2	2	2·91	2·77

IRON GUNS.		Length. Ft. In.	Weight. Cwt. Qrs.	Calibre of Gun. Inches.	Calibre of Shot. Inches.
Heavy	42-pr.	9 6	65 0	7·3	6·68
	32 „	9 6	55 0	6·42	6·10
	24 „	9 6	49 0	5·83	5·54
Light	24 „	9 6	47 0	5·83	5·54
	18 „	9 0	40 0	5·29	5·03
Heavy	12 „	9 0	32 0	4·63	4·40
Medium	12 „	8 6	31 0	4·63	4·40
Light	12 „	7 6	29 0	4·63	4·40
	9 „	9 0	29 0	4·21	4·0
	9 „	8 0	27 0	4·21	4·0
	9 „	8 0	26 0	4·21	4·0
	6 „	9 0	24 0	3·66	3·48
	6 „	8 6	23 0	3·66	3·48
	6 „	8 0	22 0	3·66	3·48
	4 „	6 0	12 0		
	4 „	5 6	11 0		
	3 „	4 6	7 0		

BRASS HOWITZERS.	Length. Ft. In.	Weight. Cwt. lbs.	Calibre. Inches.	Diameter of Shell. Inches.	Charge. lbs. oz.
8-inch.	3 1	4 0	8	7·75	3 8
5·8 „	2 2	4 0	5·62	5·50	1 0
4·5 „	1 10	2 10	4·52	4·40	8

BRASS MORTARS.	Length. Ft. In.	Weight. Cwts. Qrs.	Calibre. Inches.	Diameter of Shell. Inches.	Charge. lbs. oz.
For Sea Service.	5 3	82 0	13	12·75	30 0
	4 9	53 0	10	9·75	12 8
For Land Service.	3 8	25 0	13	12·75	10 0
	2 9	11 0	10	9·75	3 12
Royal	1 4	1 0	5·62	5·50	9
Coehorn	1 1½	0 3	4·52	4·40	5

The dimensions of British guns, mortars, and howitzers were not altered again until the beginning of the present century, when *heavy brass ordnance* ceased to be cast, and the weight and dimensions, as shewn in the article 'Artillery,' was adopted. It would appear that until the close of the American War, our armies were encumbered with heavy artillery, the weight of guns and carriages being out of all proportion to the means of moving them with facility.

The next change, as involving an alteration in the armament of ships, was the introduction of the carronade, about the end of the 18th century. This enabled small vessels and the upper decks of larger ones to carry a piece of ordnance of large calibre, viz. 18-pr., 24-pr. and 32-pr. carronades, previous to which the vessels were armed with heavy 9 and 12-pr. iron guns.

At the commencement of the French Revolutionary War, the organization of the British artillery for the field was very imperfect; but it is a question whether, in the exercise of great guns and the nature of our heavy ordnance, much improvement has taken place, as may be proved by adverting to the siege of Gibraltar.

This fortress was attacked in October, 1779, and sustained a combined siege and blockade for four years; the besiegers commencing with 35 pieces of ordnance,

which increased to 400 of the heaviest calibre; the final attack being a combined operation of sea and land batteries, which terminated in the destruction of the former with red-hot shot, and in raising the siege. This was probably the first successful attempt in the use of hot shot against shipping.

In the early campaigns of the war with France, in 1795, 98, and 99, in Flanders and Holland, light brass ordnance only were used, when two field-pieces were attached to each battalion of infantry, who assisted in the working of the guns: the horses, procured in the country, were in single harness, and driven by waggoners in smock-frocks.

In the expedition to Egypt, in 1800, a little advance was made in the equipment of the Foot Artillery. In that campaign, after the battle of Alexandria, to which period the field-pieces were drawn by seamen from the fleet, and the army proceeded to Cairo, a sort of Horse Artillery was formed from the companies of Foot Artillery, under Captain Alexander Macdonald, and organized as follows:

Each piece of light artillery had attached to it 1 non-commissioned officer, 7 gunners, 3 drivers, and 10 horses, distributed thus:

1st, pair of leaders,	with	1 driver.
2nd, „	„	2 extra artillerymen, mounted.
3rd, „	„	1 driver and 1 artilleryman.
4th, „	„	2 artillerymen, mounted.
5th, wheel horses,	„	1 driver and 1 artilleryman.
		2 artillerymen on the limber.

In coming into action, the artillerymen dismounted from the limber and horses, whilst the drivers took the limber to the rear: 60 rounds were carried upon the limber, and the spare ammunition was conveyed by camels. A heavy brigade of 12-pounders, drawn by bullocks, was formed under the late Major-General Adye.

The organization of the horse artillery took place in 1793, and the formation of this important arm necessarily led to the improvement of the foot brigades, as they were termed, until the close of the war. The first attempts at moving field artillery with more than ordinary celerity were made under the direction of Colonel Griffith Williams, Commandant at Woolwich, in 1788–9, by means of what were termed curricle guns, when the Duke of Richmond was Master-General, this Officer having had great experience in the campaigns in Germany and America. (*Vide* MS. folio in the Royal Artillery Library at Woolwich.)

The first foreign service in which the British horse artillery was employed was that at Buenos Ayres, in South America, in 1807. This Service particularly distinguished itself in the campaigns in Portugal, Spain, and France, from 1809 to 1815.

Some discussion has arisen upon the comparative merits of horse and foot artillery: each has its peculiar advantages, and it is only on the misapplication of their services that any comparison can be made. Where celerity* is required, when artillery is necessary in difficult and in almost impracticable positions, the horse artillery is

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* Captain Eardley Wilmot, of the Royal Artillery, gives the following evidence before the Select Committee of the House of Commons, in 1849, on the Ordnance Expenditure:

"I would mention an anecdote which was told me yesterday; it was in a letter written by an Officer commanding a troop of horse artillery in the late campaign in India. The writer states that he was commanding a troop of horse artillery with nine-pounders; that he was sent in pursuit with General Gilbert's force: they began at a gallop, came down to a canter, a trot, and at last came to a walk; the horse artillery armed with six-pounders galloped by them, and only pulled up when the cavalry pulled up, and was with them at the very end of the pursuit."—(See also Appendix II.)

incomparably superior; but to accompany infantry movements, and where weight of metal is to tell against an enemy, the foot artillery is the proper arm: and it is not exceeding the truth to assert, that the efficiency of the latter depends greatly upon the perfection of the former, and that the horse artillery is the best school for Officers before commanding foot batteries as now equipped.* (See the article '*Equipment of Artillery*,' Tables I. II. and III., of this work.)

The improvement on what may be deemed the efficiency of the foot batteries commenced after the Peace of Amiens, in 1801, when the corps of artillery drivers was properly organized, with the introduction of cars for the ammunition, and the gunners were carried on them: hence the batteries were called 'car brigades:' these were substituted for ammunition waggons, as at present used, (see Plates XXVII. and XXVIII. article '*Carriage*,') and the batteries formed of 5 light guns and 1 howitzer.

In the early campaigns of the Peninsula, at the battle of Vimiera the batteries were composed principally of 3-prs. and $4\frac{2}{5}$ howitzers; but as the officers and men of the Royal Artillery became more experienced in the field, the batteries were composed of 6-pr. guns with the light 24-pr. howitzers, and the 9-pr. gun associated with the heavy 24-pr. howitzer; but these howitzers have been changed for Miller's brass gun howitzers, the 24-pr. of 12 cwt. being attached to the 9-pr. guns, and the 12-pr. of $6\frac{1}{2}$ cwt. attached to 6-pr. guns. The 9-pr. guns were employed to cope with the French 8-pr. guns.

It is not, however, the perfection of the equipment alone that is necessary; it is practical knowledge in presence of an enemy, in countries in which it is difficult to move, and where forage is scarce and good stabling very rare, that makes artillerymen competent to bring their guns into action fresh, and perfect in all their attributes. Hence it was that the French, after fifteen years' experience in Germany and Italy, were always able to bring into action, in the Peninsular campaigns, with far inferior equipment and horses, a greater number of guns with heavier metal. In fact, at the early period of the Revolutionary War, the French separated the movements of artillery from infantry, although attached to them, learnt the art of acting independently, and of bringing their guns to bear upon important and vulnerable points. (See the Memoirs of the French General of Artillery, Baron Senarmont, who was killed at the siege of Cadiz, 1810.)

The equipment of field artillery, although decided by a Committee of Officers in 1819, based upon the experience of the previous campaigns, is yet a subject of discussion; and it has been thought, that if the 24-pr. howitzer could be reduced in weight, and the light 6-pr. gun increased to 150 times the weight of the shot, or 8 cwt., these pieces might be adapted to horse artillery. It has also been conceived that 32-pr. howitzers should be associated with the 9-pr. guns for foot artillery, to cope with the French howitzers of 16 centimètres which accompany their 8-pr. brass guns. It appears that three of the troops of horse artillery were equipped in the campaign of 1813 with long 6-pr. guns and heavy $5\frac{1}{2}$ howitzers, when no difficulties occurred.

Heavy Ordnance, for Land Service, of iron, now exclusively employed in the attack of places and in the armament of forts and fortresses and for coast defences, are constructed upon nearly the same principle as regulated by General Armstrong and Desaguliers, and proposed in the experiments of Mr. Robins, which did good service at the sieges

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* By this we presume is meant, that there must be some standard of value: for example, in the Peninsular War, the light infantry division was considered the élite of infantry; the dragoons of the King's German Legion as the élite of the cavalry, and the horse artillery as the élite of the whole army: these serving as a pattern for emulation.—*Editors.*

of Havannah, Belleisle, and Gibraltar, and at the Peninsular sieges when brought into use.

Sea Service Ordnance, also of iron, for the armament of ships of war, since the adoption of the heavier metal (à la Paixhan's), for shells and hollow shot, has received a new application, the 32-pr. gun being the smallest calibre in use of different weights, so as to suit the lower, middle, and upper decks of vessels: these are associated with the 8-inch and 10-inch iron shell guns, in the proportion of one-tenth for sailing vessels, and about one-half for steam vessels. The admixture of 8 and 10 inch guns seems likely to lead to confusion in time of action, and to be otherwise apparently unnecessary.

To save expense, and appropriate many short heavy iron guns cast for sea service, several 18-prs. and 24-prs. have had their bores increased to carry a 32-pr. shot, and serve, as before explained, for the upper decks of ships of war. (See Artillery Tables, A. and B., and Appendix I. to this article.)

This new armament has nearly doubled the force of our Navy since the Peace, as the following Table, taken from the Report of the Committee of the House of Commons on the Ordnance Department in the Session of 1849, will explain.

COMPARATIVE BROADSIDE WEIGHT OF SHOT.

In the year 1806.			In the year 1849.		
Number of Guns.	The 'Britannia,' of 102 guns.	Weight of Shot.	Number of Guns.	The 'Caledonia,' of 120 guns.	Weight of Shot.
		lbs.			lbs.
28	32-pounder guns .	896	12	8-inch guns . .	816
28	24 " " .	672	94	32-pr. " . . .	3008
36	12 " " .	432	14	32-pr. carronades	448
10	32-pr. carronades.	320			
	Total weight of shot . . .	2320		Total weight of shot . . .	4272
	Broadside weight of shot in 1806	1160		Broadside weight of shot in 1849	2136

The problem as to the effect of the fire from this heavy armament, in future Naval engagements, has to be solved, and without the aid of steam will probably produce a series of tactical operations of an undecided nature. Against land batteries, the relative strength will remain the same when the heavy guns are used for the defence of coasts and harbours.

It has been suggested, in order to secure a consistency in the demands of heavy ordnance for the Land Service, for coasts, harbours, and sea faces of fortresses, that they might be classified so as to establish some uniformity for the Artillery Service in the following manner:

Class A. To embrace the armament of batteries for open shores and isolated spots, where ships of war could not approach within 1200 yards.

Class B. The armament of works for the protection of roadsteads and anchorages within 3000 yards.

Class C. The armament of works for the defence of harbours and mouths of navigable rivers.

CLASS A.

would provide for coast defences on open shores and isolated spots, which usually consist of small batteries, open or enclosed in the rear, protected by a tower or block-house or defensive barrack, to serve as a keep, or by a tower capable of mounting one, two, or three heavy guns. The ordnance most suitable for these positions might be the 32-pr. long gun or the 24-pr. long gun; the keep to have one howitzer, corresponding with the calibre of the guns in the battery, and the whole to be supplied with 50 rounds of ammunition per piece.

CLASS B.

For the armament of works for the protection of anchorage, the 56-pr. long Monk's gun, associated with the 32 or 24 pounder gun, where the battery is not approachable for ships of war within 500 yards, and a reverberating furnace for heating shot, with a supply of 75 rounds per piece.

CLASS C.

Works destined for the defence of harbours and the mouths of rivers require the heavy armament, consisting of the 8-inch gun of 68 cwt., with those of the same calibre of 50 cwt., for hollow shot and shells; the number of guns corresponding with the importance of the site. Two or more heavy mortars, if there is anchorage within 3000 yards, should likewise be mounted; the allowance of ammunition being 100 rounds per piece of ordnance.

CONCLUSION.

The object of this paper is to record the first attempts in the art of gunnery and the progressive advance and improvements in the construction of British ordnance, framed from MSS. in the Library of the Royal Artillery, from the works of various authors upon this subject, from information derived from Officers who served in the campaigns previous to the Peace of 1815, and from some experience in the field.

Although the equipment of artillery, at this time, appears as near perfection as possible, yet it would be the height of presumption to say that it can go no further. "Quarter-Master Wm. Tate, of the 8th Battalion, states, that in 1798 he was on a detachment drilled at Woolwich. It was called experimental drill; and when reviewed by the Commandant, with 3 horses to each gun in length, and driven by contract drivers, clothed in short white frocks with blue cuffs and collars, and a waggon-whip over the shoulder, Captain Spearman, then Garrison Adjutant, observed to General Lloyd, that it was impossible the movements could be quicker performed, to which the Commandant assented!"

W. C.

Gibraltar, December, 1849.

APPENDIX I.*

List of Guns supposed to have been in use in the year 1682, as found in a Ledger at present in the Tower.

Cannon of 8 inches, 11½ and 10½ feet in length.
Cannon of 7 inches, 12, 11, 10½, 10, 9½, 9, 8½ do.
Demi-Cannon, 32-pr., 13, 12½, 12, 11½, 11, 10½, 10, 9½, 9, 8½, 8 do.
,, 24-pr., 14, 13, 12, 11, 10, 9, 8½, 8, 7½, 7 do.

* Presented by Colonel Dundas, C. B., R. A., Inspector of Artillery, Royal Arsenal, Woolwich.

Culverin, 18-pr., 12, $11\frac{1}{2}$, 11, $10\frac{1}{2}$, 10, $9\frac{1}{2}$, 9, $8\frac{1}{2}$, 8, $7\frac{1}{2}$, 7, $6\frac{1}{2}$, 6, $5\frac{1}{2}$, 5, 4 feet in length.

„ 12-pr., 11, $10\frac{1}{2}$, 10, $9\frac{1}{2}$, 9, $8\frac{1}{2}$, 8, $7\frac{1}{2}$, 7, $6\frac{1}{2}$, 6, $5\frac{1}{2}$, 5, $4\frac{1}{2}$, 4 do.

Demi-Culverin, or 9-pr., 12, $11\frac{1}{2}$, 11, $10\frac{1}{2}$, 10, $9\frac{1}{2}$, 9, $8\frac{1}{2}$, 8, $7\frac{1}{2}$, 7, $6\frac{1}{2}$, 6, $5\frac{1}{2}$, 5, $4\frac{1}{2}$, 4 do.

„ 8-pr., 10, $9\frac{1}{2}$, 9, $8\frac{1}{2}$, 8, $7\frac{1}{2}$, 7, $6\frac{1}{2}$, 6, $5\frac{1}{2}$, 5, $4\frac{1}{2}$, 4 do.

„ 6-pr., $10\frac{1}{2}$, 10, $9\frac{1}{2}$, 9, $8\frac{1}{2}$, 8, $7\frac{1}{2}$, 7, $6\frac{1}{2}$, 6, $5\frac{1}{2}$, 5, $4\frac{1}{2}$, 4, $2\frac{5}{8}$ do.

Jaker, $4\frac{1}{2}$-pr., $10\frac{1}{2}$, 10, $9\frac{1}{2}$, 9, $8\frac{1}{2}$, 8, $7\frac{1}{2}$, 7, $6\frac{1}{2}$, 6, $5\frac{1}{2}$, 5, $4\frac{1}{2}$, 4, $3\frac{1}{2}$, 3 do.

Minion, 4-pr., 10, $9\frac{1}{2}$, 9, $8\frac{1}{2}$, 8, $7\frac{1}{2}$, 7, $6\frac{1}{2}$, 6, $5\frac{1}{2}$, 5, $4\frac{1}{2}$, 4, 3 do.

„ 3-pr., $8\frac{1}{2}$, 8, $7\frac{1}{2}$, 7, $6\frac{1}{2}$, 6, $5\frac{1}{2}$, 5, $4\frac{1}{2}$, 4, $3\frac{1}{2}$, 3, $2\frac{5}{8}$, $2\frac{1}{2}$, 2 do.

Falcon, 9, $8\frac{1}{2}$, 8, $7\frac{1}{2}$, 7, $6\frac{1}{2}$, 6, $5\frac{1}{2}$, 5, $4\frac{1}{2}$, 4, $3\frac{1}{2}$, 3, $2\frac{1}{2}$, 2, $1\frac{2}{3}$ do.

Falconet, $7\frac{1}{2}$, 7, $6\frac{1}{2}$, 6, $5\frac{1}{2}$, 5, $4\frac{1}{2}$, 4, $3\frac{1}{2}$, 3, $2\frac{5}{8}$, $2\frac{1}{2}$, 2 do.

Rabbonet, $3\frac{1}{2}$, 3, $2\frac{1}{2}$, 2 do.

Gun of $1\frac{5}{8}$-inch bore,		$3\frac{1}{2}$ feet in length.	
Do.	$1\frac{1}{2}$	„	5 do.
Do.	$1\frac{1}{4}$	„	5, 3, $2\frac{1}{2}$ do.
Do.	$1\frac{1}{8}$	„	4, $2\frac{1}{8}$, 2 do.
Do.	1	„	4, 3, $2\frac{1}{4}$, 2 do.
Piece with 7 bores.			

Port-piece of 10 inches in diameter.
Pieces with several bores.
Bases.
Chambers.
Sling-pieces.
Murderers.

An account or list of Brass Field Ordnance used in the British Service, either made new or received at the Royal Brass Foundry at Woolwich, in the year 1777, and the three or four subsequent years, to be re-cast: but by a Ledger of Ordnance Stores bearing date in the year 1682, which was saved when the Ordnance Records kept in the Tower were consumed by the fire that destroyed the Small-Gun Armoury, it appears that previous to that year the same pieces had been in use.

24-pr.,	$10\frac{1}{2}$ feet long,		52 cwt.
Do.	$9\frac{1}{2}$	„	50 „
Do.	9	„	48 „
18-pr.,	$10\frac{1}{2}$	„	45 „
Do.	9	„	43 „
12-pr.,	$9\frac{1}{2}$	„	30 „
Do.	$8\frac{1}{2}$	„	26 „
Do.	$7\frac{1}{2}$	„	23 „
9-pr.,	6	„	$13\frac{1}{2}$ „
Do.	6	„	$11\frac{1}{4}$ „
Do.	$5\frac{1}{2}$	„	9 to $8\frac{1}{2}$ do.
8-pr.,	9	„	15 „
Do.	8	„	17 „
6-pr.,	9	„	13 „
Do.	$7\frac{1}{2}$	„	$12\frac{1}{4}$ „
Do.	7	„	14 „
Do.	$6\frac{1}{2}$	„	$9\frac{1}{2}$ „
Do.	$5\frac{1}{2}$	„	6 „

$5\frac{1}{4}$-pr.,		7	feet long,	10 cwt.
4-pr.,		$7\frac{1}{2}$	„	$15\frac{1}{4}$ „
Do.		6	„	$4\frac{1}{4}$ „
Do.		$4\frac{1}{2}$	„	4 „
3-pr.,		7	„	10 „
Do.		$4\frac{1}{2}$	„	5 „
Do.		$3\frac{1}{2}$	„	4 „
Do.		3	„	3 „
Falcons,	$2\frac{1}{4}$-pr.,	6	feet long,	6 to 7 cwt.
Do.	$2\frac{1}{4}$ „	3	„	2 cwt.
Falconettes,	$1\frac{1}{2}$ „	6	„	9 „
Pattereros,	1 „	4	„	2 „
Rabbonets,	$\frac{1}{2}$ „	$5\frac{1}{2}$	„	2 „
Mortars,	13-inch.			
Do.	10 „			
Do.	8 „			
Royal Coehorns,	$5\frac{1}{2}$ „			
Coehorns,	$4\frac{2}{5}$ „			

About the middle of the last century, the number of different natures and descriptions of Brass Field Ordnance had been very considerably reduced: many of those before enumerated had been re-cast between the years 1740 and 1750, in which latter year the guns intended for the Land and Field Service were as follows:

	24-pr.,	8 feet long,	41 cwt.	Ammuzette, 1-pr.,		6 feet long,	2½ cwt.
	Do.	5½ „	16 „	Mortars,	13-inch.		
	12-pr.,	6½ „	21 „		10 „		
	Do.	5 „	9 „		8 „		
	6-pr.,	8 „	19½ „		5½ „		
	Do.	5 „	10½ „		4⅖ „		
	Do.	5 „	9 „	Howitzers,	10 „		27 cwt.
Battalion	Do.	4½ „	5½ to 6		8 „		14 „
Guns,	3-pr.,	7 „	11½ „		5½ „		4¾ „
	Do.	3½ „	2½ „		4⅖ „		2½ „

After the year 1790, the guns for Field Service were—

	12-pr.,	6½ feet,	21 cwt.	Mortars,	13-inch.	
	Do.	6½ „	18 „		10 „	12¾ cwt.
	Do.	5 „	12 „		8 „	6½ „
	9-pr.,	6 „	13½ „		5½ „	1¼ „
	6-pr.,	7 „	12 „		4⅖ „	¾ „
	Do.	5 „	6 „	Howitzers,	10 „	27 „
Battalion Guns,	Do.	4½ „	6 „		8 „	14 „
(discontinued	3-pr.,	6 „	6 „		5½ „	heavy, 10 „
about 1802,)	Do.	4 „	3 „			light, 4¾ „
	Do.	3 „	2¼ „		4⅖ „	2½ „
Ammuzette,	1-pr.,	5 „	2½ „			

Return of Iron Ordnance for Sea and Land Service used in the Armament of Ships and Forts in 1849.

		Ft.	In.	Cwt.	
These guns have been adopted into the Service since 1828.	10-inch.	9	4	85	for Naval purposes only.
	8 „	9	0	65	for General Service.
		8	10	60	for Naval Service.
		8	0	52	
		6	8½	50	for Land Service.
	68-prs.	10	10	112	do.
		10	0	95	for Naval Service.
		9	6	88	
	56 „	11	0	98	for General Service.
		10	0	87	for Land Service.
	42 „	10	0	84	do.
		10	0	75	
		9	6	67	
The guns here designated have been in the Service since 1782, and many of them for half a century prior to that date.	32 „	9	7	64	do.
		9	6	56	for General Service.
		9	0	46	for Naval Service.
		8	0	48 to 50	do.
		9	0	a 50	for Naval Service only.
		8	6	b 45	
		8	0	c 42	
		8	0	41	for Naval Service.
		7	6	40	do.
		7	6	39	do.
		6	6	32	for General Service.
		6	0	25	for Naval Service only.
		5	4	25	

		Ft.	In.	Cwt.	
The guns here designated have been in the Service since 1782, and many of them for half a century prior to that date.	24-prs. Congreve	9	6	50	
		9	0	48	
		6	6	33	for Land Service.
	18-prs.	9	0	42	do.
		6	0	20	for Naval Service.
		5	6	15	
	12 "	9	0	34	for Land Service.
	6 "	6	6	18	
		6	0	17	
Carronades,	68-prs.	5	4	36	but little used in either Naval or Land Service.
	42 "	4	6	22	
	32 "	4	0	17	
	24 "	3	9	13	
	18 "	3	4	10	
	12 "	2	8	6	
	9 "	4	0	8	
	6 "	2	9	$4\frac{3}{4}$	

APPENDIX II.

*Comparative View of Horse and Brigade Artillery, by Major-General Sir Robert Gardiner, of the Royal Artillery.**

"An objection has been put forth by persons who can know nothing of the Services, against the employment of horse artillery. There can be no greater mistake than to put in rivalry or comparison, or to expect the same results from, the employment of horse artillery as of brigade artillery: though one and the same arm, they are equipped and intended for totally distinct purposes. The necessary quick movements of the horse artillery could not be attained by 9-pounders: the telling effects of 9-pounders could not be expected from horse artillery. One is intended to act with cavalry, and, from the nature of its equipment, and the lightness of its metal, is expected to maintain at all times, and under all circumstances, of bad roads, of rough, hilly, or broken ground, the same pace as cavalry; and, in short, to bring artillery into action wherever cavalry can act.

"One unquestionable advantage held by horse artillery over artillery differently equipped, is to be able to move, manœuvre, and bring guns into action, in a country and under circumstances in which it would be impossible for other guns, differently horsed and equipped, to move at all. I can name two instances in which, while acting with cavalry, any other than horse artillery would have been perfectly useless. One, the affair of Morales in Spain; the other, the movement from Quatre Bras to the position of Waterloo. Both were especially movements of horse artillery, and both fairly tried the wind and speed of our horses. In the latter movement particularly, through a heavy cross country, any artillery, differently equipped, would have inevitably fallen into the hands of the enemy.

"In all light movements of the infantry of an army, horse artillery is as indispensably necessary, and as exclusively effective, as it is with cavalry. I have myself, in case of reconnaissances, been withdrawn from the cavalry for the moment, to cover movements in which heavier artillery could bear no part.

"I would instance also occasions in which brigade artillery always failed, and frequently exposed themselves to unavailing danger in the attempt. On one occasion

* Extracted from a 'Report of the Numerical Deficiency, Want of Instruction, and inefficient Equipment of the Artillery of the British Army.'

in particular, when in pursuit, it was only from the unnecessary haste and panic of the French cavalry that the brigade was not cut to pieces.

"On the other hand, if horse artillery has its distinct advantages over heavier guns, so likewise the latter has the distinct purposes for which the employment of horse artillery would be wholly inapplicable and inadequate. In position, and for all purposes of field defence, or breaking heavy masses of approaching troops, the 9-pounder is the most perfect gun that can be brought into the field."

ORDNANCE, Construction of.

PRELIMINARY REMARKS.*

The substances found applicable to the construction of ordnance are cast iron and bronze or gun-metal, which forms what are commonly, but erroneously, termed brass guns.

Cast Iron. Cast iron is produced from the ores of that metal by the operation of smelting.

The iron ordnance for the British Artillery has invariably been supplied by contract, whether for Sea or Land Service; the ponderous nature of the material making the casting on the spot advantageous, where the ore and fuel are obtained, and the great practical experience at the foundries rendering this arrangement economical.

Iron ordnance, being much cheaper than bronze, are used in garrisons, battering trains, and at sea, where lightness is not of so much importance.

The specific gravity of iron gun-metal varies from 7·248 to 7·328, a cubic foot weighing from 453 to 458 lbs.

All the bronze or brass ordnance in the Service are cast at the Royal Foundry at Woolwich.

Copper. Copper is a very ductile and malleable metal: it has great tenacity, and resists the action of exploding gunpowder better than any other metal; but pure copper would be too soft for guns, it would be liable to external injury, and the bore would be soon indented. Its specific gravity is 8·607: it fuses at 2500°.

Tin. Tin is malleable, but not very ductile; it is very soft: its specific gravity is 7·291: it melts at 442° Fahrenheit.

Gun-Metal. Gun-metal is an alloy of copper and tin; it is more sonorous and harder, less susceptible of oxidation, and much less ductile than either of its components: the admixture of the tin hardens the copper, and a large increase in its proportion would render the alloy exceedingly brittle. The proportions are from 10 to 12 parts of tin to from 90 to 88 parts of copper. The specific gravity of the composition is 8·748, being greater than that of either of its components: it fuses at about 2000° Fahrenheit.

Bronze. Bronze is an alloy of 11 parts of tin to 100 parts of copper, which is nearly the same as the proportions in gun-metal.

Bell-Metal. Bell-metal consists of 22 parts of tin and 78 of copper.

All guns are cast solid, and of rather greater diameter than they are required to be when finished, and some feet longer.

PART I.—CASTING OF IRON ORDNANCE.†

In England, Cast-Iron Ordnance are made for the Service of the Government at the establishments of private founders, who are furnished from the Ordnance Department with the drawings and constructions of such pieces as may be required from

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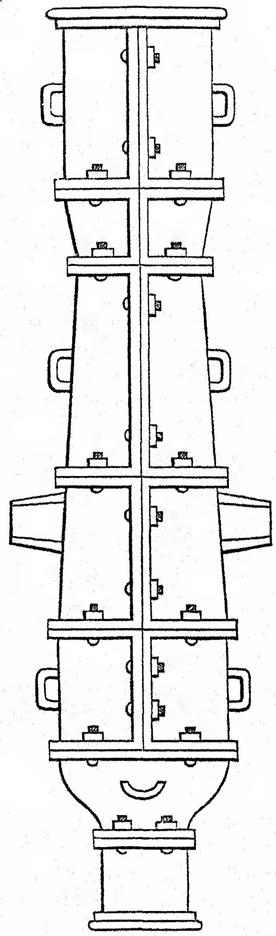
* By Lieutenant De Moleyns, R. E. † By Colonel Dundas, C.B., R.A., Inspector of Artillery.



them, and which they deliver complete into the Royal Arsenal at a contract price previously stipulated for; being held responsible for any inaccuracy in form, for defects of metal, and for casualties during proof.

The principal gun-founders of the present day who are employed, are the Low-Moor Company, whose works are near Bradford in Yorkshire, and the Messrs. Walker, of Gospel Oak, in Staffordshire. The Carron Company, who for long sustained the highest character as cannon-founders in Britain, have of late years turned their attention to other, and, to them, more profitable work.

The following is the usual process of manufacture. A model representing the piece to be cast is made either of some species of hard wood, well seasoned, or of cast iron, for greater durability. The principal part of the model includes the base-ring of the gun, the chase and head, of sufficient length to render the metal more dense, the cascable being separate from the rest: proper allowance must be made for shrinkage, generally ·08 of an inch in the foot in length; in its diameter, however, it is but little affected by contraction in cooling.

A jacket, gun-box, or case, made of cast iron, wherein to form the mould, is required: it usually consists of twelve parts, each of which has flanges perforated at the edges with holes for screw-bolts and nuts, to connect the parts together. The two lower pieces are single, not being, as is the case with the remainder, divided longitudinally into pairs.

The best material for lining the jacket, *i. e.* forming the mould, is dry, sharp, angular and refractory sand, which is to be moistened with water in which strong clay has been dissolved, to make it more adhesive.

To form the Mould.

The operation is commenced by placing upon a board the pattern of the breech, which has been previously covered over with charcoal dust, moistened with clay water, forming what is called blacking, to be used as a paint to prevent adhesion, and surrounding it with the corresponding parts of the jacket; and when nicely adjusted, the sand, prepared as before described, is well rammed in between the box and the model: the parts which follow, those for the charging cylinder, are then firmly and correctly screwed, and the prepared sand is rammed in as before, taking care that the blacking be used over the whole model. The next pair, containing the trunnions, is then screwed on, and filled in, and so on in succession of pairs, until the whole is complete: it is usual to place thin wedges of wood between each successive pair of pieces, to avert the inconvenience that would arise from the contraction of the sand during the after operation of drying.

When the whole gun is moulded, the parts of the case are carefully taken asunder, to release the model, and the several portions of the mould formed within and adhering to the jacket are placed in a drying stove, where they must be gradually but perfectly dried: here they remain from twelve to fourteen hours: when sufficiently dry, the parts of the case are carried to the pit, where they are joined together, and then secured therein in a perfectly upright position, in which the whole must be firmly fixed by means of suitable props. In the latter part of the operation, *i. e.* in joining the jacket, it is necessary that any portions of the sand lining forming the mould which may have been broken off or disturbed, should be replaced, and the whole of the interior be covered with the blacking before described. The mould is now ready to receive the melted metal, which is made to flow into it at the open top.

Some gun-founders use a basin or hollow disk of very soft and easily-fusible cast iron, placed at the bottom of the mould, to receive the falling metal, thereby to prevent injury, and to keep out slag or other foreign matter from that lower portion of the mould where the bottom of the cascable is formed, and for the like purpose two perforated thin plates of the same material are used to cover the openings of the trunnions, by which means it is said that better and more perfect castings are made than when these precautionary measures are not taken.

The metal commonly used by gun-founders is principally in pig, run from the ores found overlaying the coal near where the works are established; but as the quality of the metal there produced may not always be such as will insure the fabrication of good guns, it is usual to mix metals possessing those qualities which may be wanted, such as Blaenarven (Welsh), Shropshire, Yorkshire, or Cumberland irons, the last of which is made from the red hematite ore, found in large quantities in that county.

The metal in pigs made use of is generally of three or four different qualities, chosen with great judgment and care from what is commonly known under the designation of Nos. 2, 3, and 4 of the best natures of British cold-blast iron, so proportioned as to produce a sufficiently hard, strong, tough, and, above all, elastic metal; the heads from previous castings being considered as No. 4. The experienced workman, whose character depends upon the soundness and excellence of his work, will be careful to avoid extreme hardness as well as softness in the compounded metal, as being qualities unfit for the purpose for which it is intended. The metal is melted in one, two, or more reverberatory furnaces, as the case may require, each capable of holding from three to four tons; the fuel being that species of bituminous coal which contains the smallest amount of impurity, that greatly sulphureous being unfit for use.

When the metal is ready, which the practised eye of the workman correctly determines, the run-hole, which had been stopped by means of a lump of loam, is opened; and should there be more furnaces than one employed on the cast, that in which the metal is the hottest is first tapped, and the metal from it is allowed to run into a basin formed in sand conveniently near the mouth of the mould, and then the remainder in succession; and when the whole from the several furnaces becomes mixed, and the furnace-man in charge considers it to be in a proper state, it is allowed to pass into the mould.

The casting stands in the pit undisturbed for twenty-four hours before it is taken out, and it generally continues for the same length of time in its earthy covering before it is released: a few blows of a hammer are sufficient to clear it: it is then prepared for the lathe, where the head is cut off by making perfect the square lump left at the end of the cascable; and when that operation is finished, it is placed upon the boring-bench: generally three boring-bits are used in succession before the bore is complete, and if no flaw or other imperfection be observed, it is removed to the turning-bench, where such parts of the gun as can be touched by the tool are

brought to their proper dimensions. Again the gun is carefully examined, both internally and externally, and if no fault be found with it, it is removed to the machine for turning the trunnions, after which it is vented and finished, either by chipping and filing, or partially by machinery.

PART II.—THE MANUFACTURE OF BRASS CANNON IN THE ROYAL BRASS FOUNDRY.*

The operation of moulding Brass Cannon is as follows.

A model of the gun, somewhat enlarged in its several parts, is formed upon a wooden conical mandrel wrapped round with straw plait, over which is applied a mixture of sand and horse-dung, with water to bring it to a proper consistence; and when it is complete with its trunnions (and dolphins, if wanted,) and brought to a smooth surface, and covered over with some material in a liquid state, to prevent adhesion in the after process, it is ready to give the impress to the mould, which is formed upon it with well-worked moist loam, mixed with cow-hair, applied in concentric and successive layers, and into which the long fibres of hemp are carefully worked, each layer being, to a certain extent, dried over a charcoal fire made within the moulding-frame upon which the mandrel is placed; and this is continued until there is a sufficient body and resisting power in the mould, upon which strips of hoop-iron are longitudinally laid, and all then carefully bound round with hoops, under which, in consequence of the contraction of the mould in drying, wedges of wood are driven, to keep all tight and secure: it is finally covered over with the same kind of loam mixed with water, and then carefully dried on the frame previous to the removal from within of the friable material which has formed the model; and this is done by a moderate blow or two being given on the smaller end of the mandrel: the mould is then slowly but perfectly dried before it is placed in the casting-pit.

The mould of the cascable of the gun, and that of the dead-head, are prepared separately, and that of the latter is now joined to the top of the mould.

The number of moulds required to fill the pit are placed therein, and any moisture which may remain in them must be expelled by fires made with old hop-poles within each mould; and being thoroughly burnt, or, to use the technical term, annealled, which will be effected by keeping up the fires for three or four hours, they are ready for use: equal care is taken in drying the moulds of the cascables, which are placed on the bottom of the pit to receive the gun-moulds, and also that the joints be well stopped, to prevent any escape of metal: the entire mould is then to be brought into a perfectly upright position.

The moulds are after that well and carefully secured in their places by means of dry sand, which is firmly rammed around them until the pit is full, and then proper channels for the run of the metal are formed with fire-bricks, in doing which every precautionary measure is taken to insure the liquid metal being kept under all necessary command while passing from the furnace.

The metal, which is an alloy of copper and tin, in the proportion generally of 92 of the former to 8 of the latter, having been melted in a reverberatory furnace (which requires from ten to twelve hours) with well-dried billet wood, is let run into the moulds through small run-holes, one in each mould, made in the inner side near the top.

The cast remains in the pit undisturbed generally for about forty-eight hours, when it is taken out and the mould broken away from it; it is then well cleaned, and afterwards carried to the manufactory, where it is subjected to the following

* By Colonel Dundas, C. B., R. A., Inspector of Artillery.

operations in eight several machines, which are admirably contrived for the division of labour, and consequent reduction of the cost of manufacture.

In the Machine No. 1. The dead-head is cut off.

" No. 2. The mass of metal is centered, and made ready for the turning-lathe.

" No. 3. It is prepared by circles at the principal parts being turned to their proper dimensions, to guide the workmen in their future operations.

" No. 4. The trunnions are turned.

" No. 5. The metal between the trunnions is planed away.

" No. 6. Holes to receive the copper bouche and sliding tangent scale are drilled, and the joints in the button of the cascable to receive the end of the elevating screw are formed.

" No. 7. The gun is bored, and partially finished on the exterior.

" No. 8. It is wholly finished, as far as may be, by means of machinery which has been contrived for removing certain parts of the metal which turning and planing tools cannot reach.

The gun is then carefully examined previous to its being proved with gunpowder, and after by the forcible injection of water: should there have been no defects of metal or errors of construction discovered during these operations, it is removed to the finishing shop, where it is made perfect, cleaned off, and engraved.

PART III.—DESCRIPTION OF THE MACHINERY USED IN THE MANUFACTURE OF CANNON AT THE ROYAL ARSENAL, WOOLWICH.*

In no department of practical science has there been a more rapid advancement, during the past thirty years, than in the construction of machinery. Whilst many causes have operated in producing this result, there is one agency which, from its apparent simplicity, we are apt to overlook, but which has been the chief instrument in accomplishing so remarkable an improvement, namely, the introduction of the sliding-rest principle.

Before the invention of this admirable contrivance, every separate piece of work had to be performed by manual dexterity. In the process of turning, the tool was held and guided by the hand, which was ever liable to err; and in the production of any other form, the tedious operation of the chisel and file had to be resorted to; and while the work done was very imperfect, it was necessarily most expensive.

By this principle we are enabled to produce the smallest, or the most ponderous piece of work, with equal facility and mathematical precision. The tool, instead of being held by the workman, is held by an iron hand not liable to err, while the attendant, instead of exerting his physical powers to the utmost, as he previously had to do, even in producing the simplest kinds of work, has now only to direct it by his skill, and in most cases even the guiding of the tool is not left to his hand, but is regulated by the machine itself, so that the operation, as far as the workman is concerned, is entirely mental.

And not only is it in the turning-lathe that the advantages of this principle are so conspicuous, but in all our tools and machines, and nowhere are its beauties more splendidly developed than in the planing machine. By this machine we are able to produce the most perfect surfaces, whether horizontal, vertical, angular, or parallel, and with a facility and accuracy which, before its introduction, were never dreamt of;—without it, there are many parts of the machinery about to be described that could not have been executed.

* From the 8th volume of 'Papers connected with the Duties of the Corps of Royal Engineers.'

The machinery and tools employed in the manufacture of cannon in the Royal Arsenal have been constructed and erected by Mr. Napier, of London, within the last few years.

Previous to that time the manufacture was carried on in the most primitive manner. The boring mills or lathes which came from Holland about eighty-five years ago were in separate buildings, to each of which was attached a four-horse mill; upon the end of the shaft which brought the motion from the mill was a square box or chuck; into this box fitted a square, cast upon the gun behind the cascable. The muzzle of the gun ran in a circular collar-plate, which was kept firmly in its place by means of iron bolts, connected to a strong foundation of iron-work and masonry. In the process of boring, the bit was forced into the gun by means of an endless screw, with rack and pinion, which was moved by a man or boy, while the laborious operation of turning was effected entirely by the hand tool: when bored and turned, the gun was put on a carriage, and taken to another building to be vented.

Here it was placed on blocks of wood while the several holes were drilled, which was performed by two men with a crank-brace drill, the pressure being communicated from heavy iron weights placed above. The copper vent was drilled in a lathe, one end of the bolt on a centre, the other in a collar-plate: the motion was given by two men on a fly-wheel, while the drill was held in the hand of another workman. In the same lathe the vent was turned, and the screw cut upon it, both operations being performed by hand. When the copper vent was screwed into the gun, the projecting part inside was wrenched off by the workmen with a half-round bit: the gun was again put on a carriage, and taken to another building to be trunnioned.

When here, it was placed on blocks of wood, with the trunnions in a vertical position; one of the trunnions was then set off, and about a quarter of an inch of it brought to the proper size by the chisel and file. Upon this was placed a circular box, with a cutter fixed on the under side of it; on the other or upper side was fixed a vertical spindle, which received pressure from heavy iron weights hung above it. Long levers were now attached, and two or three men kept walking round and round until this part of the trunnion was completed; the extreme end of the trunnion being finished by chisel and file. The other trunnion was then turned up, and the same operation performed upon it; after which the gun was again placed upon a carriage, and taken to another building to be finished.

Such was the tedious, rude, and imperfect system in use until about nine years ago, when the necessity of a change was rendered manifest to the then Master-General of the Ordnance, the late Lord Vivian, who directed the Inspector of Artillery (Colonel Dundas) to submit for his consideration such plans as he should under the circumstances deem necessary; and the machinery then ordered, with very material and important additions authorized by Sir George Murray and the then Board of Ordnance, and other necessary machines constructed in the establishment, are now to be described.

The prime mover is an expansive and condensing steam engine of 12-horse power, which may be worked at a pressure of 30 lbs. to the square inch, if required: it has two cylindrical boilers, only one of which is used at a time. The power is transmitted from this steam engine by a large strap passing over the drum, and over a corresponding drum on the main shaft, which distributes the power over the factory.

To render the description of the machinery more distinct, let us take a gun in its rough state, as it comes from the foundry, following it through its various operations, and describing the machines as they are required to perform their several parts.

Guns are cast solid, in a vertical position, with the breech downwards: upon the muzzle or upper end the mould is prolonged from 3 to 4 feet, for the purpose of

increasing the density in the lower part of the metal, feeding the shrinkage, and allowing the sullage or any spurious substance to rise to the surface.

This elongation is technically called the dead-head.

When a cast of guns (generally eight or ten) comes from the foundry, the first operation is to cut off the dead-heads. This is done in one of the boring and turning lathes. On the breech of the gun, beyond the button of the cascable, is cast a round stud about 3 inches in diameter, and 4 or 5 inches long. This stud is for holding the centre upon which the gun revolves, and upon which is fixed the carrier whereby the gun receives its motion.

The gun is lifted by the crane into the lathe. The stud (*a*, fig. 1, Plate I.) is inserted into the box chuck (*b*). This chuck is fastened between the four jaws of the face-plate (A), which is screwed on the end of the lathe mandrel; the jaws (*c*) are moved by separate screws, so that the box chuck can be shifted on the face-plate until the body of the gun is brought to truth. To keep the gun in its place, and to give motion to it, a pair of clutches (*d*) are fastened on the neck of the cascable, and through which the bolts (*e*) connect the gun to the face-plate.

Fig. 2 is a front elevation of the head or frame, on which rests the muzzle, both in this and in the subsequent operation of boring. A is a section of the lathe bed of cast iron; B is the collar-head or frame, made of gun-metal; C, the slide-rest frame; *a a* are two steel plates fastened on the slide (D), which is the collar in which the muzzle runs, and is in the form of the letter v. This slide is made to rise or fall by two screws working simultaneously, so as to bring guns of different diameters into a horizontal position: the screws are at the back of the frame, and the handle to move them underneath.

Previous to the gun being put in the lathe, this head or frame is shifted 2 or 3 feet out of the way by means of a rack and pinion (*b*), and when the gun is apparently about its situation, made to slide back to its place; the muzzle is laid in the collar with the dead-head projecting over. The tool (*c*) is fastened in the slide-rest by the pinching screws (*d*); the pressure to cut is given by turning the wheel or handle (*e*). The tool is about one-fourth of an inch in width at the cutting part, and rather thinner behind, to enable it to clear itself.

The tool is shewn commencing the cut; the workman continues to turn the handle, and to force the tool toward the centre, until the head drops off, which it generally does when within three-quarters of an inch of the centre.

To prevent the block of metal damaging the lathe by its fall, a log of wood is laid across the bed of the lathe, about 1 inch under the head, upon which it falls. The operation of cutting off the head generally requires about twenty minutes.

The gun is now ready for the centering machine, the object of which is to find the exact centre of the mass of metal, and there to drill a conical hole at both ends of the gun, which are the centres upon which the gun is turned. Fig. 3 is a plan of this machine: A is a cast-iron bed, resting on the three legs or standards (B); the top of the bed is a Λ and flat, correctly planed, and forms a true surface for the different parts to sit or slide upon; C C are two saddles or frames resting on the bed, and fastened to it by the bolts (*h*); each of the frames has three slides, which, by turning the handle (*i*), slide to or from the centre, and are equally distant from it in every position. Fig. 4 is a side elevation: C is the saddle or frame in which are the two horizontal slides (*k*); to the saddle (C) is bolted the frame (D), which carries the vertical slide (*g*): *l* is a shaft or spindle, working in gun-metal bearings; upon this shaft are cut two screws, the one with a right-hand thread (*m*), the other with a left-hand thread (*n*): *o o* are two brass nuts, working on the screws, and fitted into the horizontal slides. Now, by turning the handle (*i*), the two slides must move in

opposite directions, the right-hand thread moving the one way, while the left-hand thread moves the other. In the frame (D), which contains the vertical slide, there is a screw (*p*) with a right-hand thread, and of the same pitch as the two others. On the top of the screw is keyed a bevel-pinion, gearing into another pinion with an equal number of teeth, keyed on the spindle (*l*); *r* is the nut on the screw, and fitted into the slide (*q*). By turning the handle (*i*) a motion is given to the screw (*p*). As the pinions contain the same number of teeth, every turn of the horizontal screw gives a corresponding turn to the vertical, and as the three screws have the same pitch, namely, four threads to the inch, the turning of the handle makes them all approach to or withdraw from the centre simultaneously.

E E, fig. 3, are two hand-drilling machines resting on the bed (A), and fastened to it by the bolts (*h*); *s* is the spindle in which is fitted the drill (*t*): by the fly-wheel and handle (F) motion is given to the spindle. The boss of the fly-wheel is let 2¼ inches into the cylinder (*u*), and kept in its place by a steel pin. The hand-wheel (*v*) is for feeding the cut.

Fig. 5 is a section of this part of the machine: a screw is cut in the boss of the wheel (*v*), into which is fitted a corresponding screw that slips loose upon the spindle; along the outside of this screw a groove is cut, into which is inserted a key that is fast in the cylinder (*u*): this key is to prevent the screw from turning while the wheel (*v*) is turned. The back part of the spindle is smaller than the drilling end, which gives a shoulder to the screw to press upon, while a pin through the spindle at the other end of the screw serves to bring it back again. A key let into the end of the spindle slides in a groove in the boss of the fly-wheel, and thereby receives its motion.

To centre a gun with this machine, it is only necessary to place it between the slides (*k*), and turn the handles (*i*) until the horizontal slides grip the gun, which brings the centre of the mass exactly opposite the centre of the drill.

The drilling heads are now brought forward, the fastening bolts are tightened, the workman with his right hand turns the fly-wheel (F), and with his other hand gently moves the hand-wheel (*v*) which feeds the cut. The whole operation, including the putting the gun into the machine and taking it out again, may be accomplished in less than a quarter of an hour. (This machine was made in the establishment.)

The gun is now ready for the boring and turning lathe; a carrier is securely keyed upon the stud, and with the crane it is lifted into the lathe and placed between the centres.

In describing the various operations, we are induced to use many technical terms; not that it is absolutely necessary, but it is as well that those who interest themselves in any subject should understand the terms by which that subject would be explained to them by those immediately concerned in it.

The centres of a lathe are those two points upon which the article revolves, or more generally, as in the present case, the one centre revolving with the work while the other is stationary.

Plate II. gives a plan of the boring and turning lathes. A is a strong and massive bed of cast iron, resting on the floor of the building; the bed is cast in two pieces, and firmly joined in the middle. The top surfaces of the bed form a Λ and flat, and are accurately planed; so that the different parts of the machine which rest upon the bed have the same relative position to one another in any situation, and without any adjustment. B is the spindle or mandrel of the lathe; it runs in gun-metal bearings or pillow blocks of beautiful construction. The principal bearing (*a*) rests on C, an elegant yet substantial pedestal of the same metal; D is the turning saddle, on which is placed the turning and planing slide-rest (E); F is the collar-frame, in

which runs the muzzle of the gun; G is the boring apparatus; *b b*, upon the shaft or axle (*c*), are the fast and loose pulleys, round which passes the strap that brings the motion from the main shaft. The fast pulley is keyed to the axle, while the other runs loosely upon it, and carries the strap when the lathe is in a state of rest.

Of all the methods which have been invented for disengaging and re-engaging machinery, there have been none to equal the simple yet beautiful contrivance of the fast and loose pulley. Unlike all the methods in use previous to its introduction, it is entirely free from shock; and in all machinery where the state of motion is not uniform, it is now universally used. The motion is conveyed to the lathe mandrel through the bevel and spur wheels. The pulley (*d*) on the mandrel is for conveying motion by a strap to the pulley (*e*), which is keyed on the end of a shaft (H), extending to the other end of the lathe, for the moving of the boring apparatus. On the end of the shaft (H), and beyond the pulley (*e*), a small bevel-pinion is keyed, which gears into a bevel-wheel on the cross shaft (*f*); this shaft carries the motion to the turning. On the shaft (*g*) are two bevel-wheels, gearing into the small pinion on the end of the cross shaft (*f*). The object of having the two wheels is to change the direction of the motion: when the slide-rest is required to move towards the right hand, the one wheel is slipped into gear, and when the opposite way, the other. When the shaft is not required in motion at all, neither of the wheels are in gear. A longitudinal groove is cut along the shaft (*g*), upon which slides a pinion with a corresponding key in it; this pinion is connected by a strap to the saddle (D), so that wherever the saddle may be placed, the slide-rest will receive a motion. The motion for turning is conveyed through the wheels (*h*) to the screw (*i*), which moves the slide-rest (E). The bed (I) upon which the rest slides is a separate casting from the saddle, and may be set at any angle, either for turning or planing. This bed is planed in the form of a dovetail, upon which the slide-rest is fitted, provision being made for tightening the rest as it gradually wears. The handle (*j*) is for moving the slide-rest to the right or left; the other handle (*k*) is for the transverse slide, that is, for advancing the tool to take a deeper cut.

That part of the gun which lies between the trunnions of course cannot be turned in the ordinary way. In turning, the gun revolves about twenty-five times per minute, or thereabout,—that depending on the size of it,—while the slide-rest travels very slowly; but in the process of planing or cutting the parts between the trunnions, the slide-rest is made to slide longitudinally the length of the part to be planed, at about forty strokes per minute, while a motion, slowly advancing toward the tool, is given to the gun. K is a lever, keyed on a rocking-shaft (L), which goes through and works in the bed of the lathe. On the top of the lever, at *l*, there is a vertical slot, in which slides a stud, or pin, fastened in an arm of the wheel (*m*), so that the rotation of this wheel makes the lever oscillate backwards and forwards a space in proportion to the radius of the stud in the wheel. There is a slot in the arm, so that the stud may be shifted, to enable the workman to make the slide-rest travel the distance he requires.

When the lathe is planing, the wheel (*n*) is put into gear with *m*, and the large bevel-wheels are disengaged. The slide-rest is disconnected from the screw (*i*); a connection is formed between the rocking lever and the slide-rest at *o o*, by means of a double connecting-rod, which can be drawn out and adjusted at any length. To produce the slow motion in the gun while being planed, *p* is a vertical lever, keyed on the end of the rocking-shaft (L); *q* is a worm-shaft, that goes through the bed and under the worm-wheel (M), which is keyed on the lathe mandrel: upon the worm-shaft there is a short screw or worm which gears into the worm-wheel while planing, and is disengaged when boring or turning. On the top of the lever (*p*) there is a pallet (*r*), which falls into the ratchet-wheel on the end of the worm-shaft. As the lever (*p*) is keyed on the

end of the rocking-shaft, it of course vibrates with it, and therefore gives a motion to the ratchet-wheel, the pallet slipping over the teeth the one way, and carrying the wheel with it the other. The stud which carries the pallet is fastened in a slot in the lever, so that it can be set to take any number of teeth, and, of course, to give a greater or less motion to the gun. The handle on the end of the worm-shaft is for bringing back the gun by hand, to take a fresh cut.

There are several projecting parts on a gun besides the trunnions; viz. the vent-field, and lump for the tangent sight, a dispart lump, and in some cases, a loop at the cascable.

In the turning of those parts, the tool has to be removed very quickly out of the way, until the projecting part is passed, and then as quickly brought back again, so that no space may be lost on either side of it. A provision has therefore been made in the slide-rest for this operation, but which, as yet, has not been used with great advantage. In the slide-rest, besides the transverse slide worked by the handle (*k*), there is a double transverse slide, not used in ordinary turning, but only for the jumping motion. This slide is not worked by a screw, but by a combination of levers in the interior of the slide-rest. The principle of action is similar to that of the elbow-joint in the human arm. When the levers are in a straight line, and therefore in their strongest position, the tool is thrown in, and cutting while the bending of the levers draws it out again. On the left-hand side of the slide-rest at *s*, there is a flange with two studs fastened in it: this flange is keyed on an axle in connection with the levers above referred to. N is a hollow shaft, with a crank (O) on the end of it. The flange *s*, with the two studs fastened in it, is part of another shaft or rod with a longitudinal groove cut in it: it fits in the hollow or crank-shaft, and slides easily out or in, but is prevented from turning in it by a key fastened in the crank-shaft, and fitting into a groove in the other.

Upon the extremity of the crank there is a friction-roller on a stud. On the side of the wheel (P), and near to the teeth, two dovetailed grooves are turned in it, for the reception of bolts: these bolts are for fixing cams on the side of the wheel at any part of the circle.

In using this part of the apparatus, a connection is formed between the flange (*s'*) on the shaft, and the other flange (*s*) on the slide-rest: two cams are fastened on the side of the wheel (P), opposite the part of the gun to be leaped over; the one cam strikes the friction roller on the crank, and throws the slide-rest back; the other cam instantly strikes it on the other side, and throws it forward, where it remains cutting until the throwing-out cam returns.

It will be perceived that the jumping motion may be in action at the same time with the self-acting turning motion, which is the case in parallel or taper turning; and if a curve has to be formed, the other transverse slide is brought into play by the workman with the handle (*k*); all the three operations working in beautiful harmony, and the boring going on at the same time.

We come now to the boring apparatus. Q is a strong frame of cast iron, resting on the ∧ and flat of the lathe bed, to which it is firmly bolted by the bolts (*r*.) G is the boring bed or bench, on which slides the boring bar. (See Plate II.)

The boring bed is strongly built of mahogany, and firmly bound with iron bolts and plates. The parts where the bar slides, the ends under the advancing screws, and those places where there are fastenings, are strongly faced with gun-metal. The object of having the bed of wood is to avoid tremor. The boring bar (R) is the instrument on which the bit for boring is fastened. In forcing the bit into the gun, there is a great tendency to twist the bit and bar round with it: to prevent this, there are three strong cross-heads (S), with a boss at each end, and a large boss in the centre, for the pressing screw, on one of the end bosses; the cross-head swivels on a

stud securely fastened in the bed. The object of having it to swivel is, that when the workman is taking out or putting in the bit, the whole thing may be turned round out of the way. The boss at the other end, that is, the end which comes to the front of the lathe, has an opening on one side, so that when the cross-head is brought to its place, the boss clasps a stud similar to the one on which it swivels. The pressing screws in the centre, which are wrought by the handles (*s*), do not press directly on the bar, but on an intervening plate connected to the cross-head.

As the boring bars differ in size, and as the boring bit always requires to be in a certain position in reference to the centre, it is therefore necessary that the boring bed rise or fall as the work may require. It is also necessary that the bed be quite level in every position. To effect this, there is a very beautiful contrivance, which is not seen in the drawing, but which I shall endeavour to describe.

The bed rests upon four large screws, at the points (*t*) in the frame (Q). Upon each of the screws there is a worm-wheel: their relative positions are shewn by the dotted circles on the bed. By turning the worm-wheels, the screws rise or fall. Along the centre of the frame (Q), and between the worm-wheels, a horizontal shaft is placed; there is a worm or screw on each end of the shaft, each worm gearing into two of the wheels. Now, by turning this worm-shaft, a motion is given to the four screws; and as the screws are of the same pitch, and the wheels have the same number of teeth, the whole must work simultaneously, and the bed is on the same level in every position. The small shaft on the frame (Q), with the handle at T, has a bevel-pinion keyed on its farther end, which gears into a bevel-wheel keyed on the worm-shaft above referred to; so that the turning of the handle (T) raises or lowers the boring bed: *u* are the heads of large bolts, which fasten the bed to the frame (Q) when the workman has brought it to its proper position. U are the screws for advancing the boring bar: they have pinions keyed on their farther end, and get their motion from a pinion on a boss of the wheel (V) not seen in the drawing. The wheel (V) may be wrought self-acting, or by hand. The handle (*v*) is for throwing the wheel out or into gear with the lathe.

As was observed before, motion is conveyed to the boring bar through the shaft (H), along which a groove is cut; a pinion, with a key corresponding to the groove, slides on the shaft: this pinion is connected to the frame (Q), so that wherever the frame is placed, it carries the pinion along with it. This pinion is connected with a bevel-wheel, keyed on the bottom of a small upright shaft, with a longitudinal groove cut in it. The lower end of the shaft is connected to the frame (Q), while its upper slides in a socket in the under side of the boring bed: a pinion on the top of the upright shaft is connected to the bed, so that the raising or lowering of the bed interferes not with the motion.

The upper pinion gears into a bevel-wheel on a short horizontal shaft under the boring bed; on the other end of this shaft there is a small spur-pinion, which, by an intermediate wheel, gives motion to the wheel (V), seen in the drawing.

The handle (*v*), for throwing the self-acting boring motion out or into gear, is the end of a lever having for its centre of motion the boss of the spur-pinion on the end of the short horizontal shaft: upon this lever the stud is fastened on which runs the intermediate wheel; so that as the lever works on the boss of the pinion, the intermediate wheel must always be in gear with it; but the raising or lowering of the lever or handle (*v*) connects or disconnects it with the wheel (V).

The method of shifting the turning saddle, the collar-frame, and the boring apparatus, on the lathe bed, is by a rack and pinion: *w w w* are squares on the end of shafts which go through to the other side, where they have pinions keyed. These pinions gear into the rack (W), which is bolted to the lathe bed. On the squares at *w* a handle in the form of a cross is placed; so that with comparative ease the workman may shift them as he requires.

Fig. 2 is the plan of a centre bar, which is used when the gun is first put into the lathe. The part *a* is fastened in the boring bed; the collar (*b*) rests in the v of the collar-frame, and is kept down by the slide (*x*); *c* is a steel centre, on which the muzzle of the gun turns. (Plate II.)

Such is but an imperfect description of this splendid tool; and although its merits need no commendation, it is right to state, that the workmanship is of the very best description, that an exuberance of mechanical skill is displayed in all its details, and that it adds another laurel to its ingenious contriver, Mr. D. Napier.

When the gun is first put into the lathe, the centre bar is fastened on the boring bed, and the centre pressed gently into the corresponding centre of the gun. The base-ring is first turned, because from it the workman takes all his measurements; he then turns and almost finishes the muzzle. The centre bar is taken down, and the muzzle of the gun is laid in the v of the collar-frame, as seen in the drawing. A drill is sent a few inches into the gun; the drill is removed, and a small slide-rest fastened on the end of the boring bed, with which the hole made by the drill is brought to the size of the first bit. The slide-rest is removed, and the bit for boring entered in the hole made for it; the bar is pressed down, but not so tight as to prevent its sliding; the self-acting boring motion is thrown into gear, the lathe is started, and the workman attends to the turning.

Bit after bit is used in the same way, until the bore is brought to the proper dimensions, while the workmen generally contrive to finish the turning about the same time. When both of these operations are finished, the planing apparatus is put in motion, and the part is finished that lies between the trunnions. The gun is taken out of the lathe, and put in the trunnion machine.

Plate III. is a plan of the trunnion machine. A is a strong and massive bed of cast iron, resting on the floor of the building; it is planed flat on its top surface. B is another bed of cast iron, somewhat similar to a lathe bed; it is planed both on its top and bottom surfaces, and firmly bolted to the bed (A). The top surfaces of the bed are in the form of two inverted v's, on which are fitted the saddles (C C). The screws (*a*) with the handles (*b*) are for adjusting the saddles with the gun, to bring it to its proper position; *c* are handles for adjusting the vertical slides (*d*); *e* is a cone centre that fits into the centre of the stud in the gun upon which it was turned; *f* is a cone that fits into muzzles of various sizes: as the trunnions of most guns are under the centre, there is an index on the face of the vertical slides, (but which is not seen in the drawing,) whereby the workman can set the gun with the utmost accuracy. When the slides are at the bottom, or as far down as they will go, the axis of the gun is on the same horizontal line with the axis of the turning spindles (G); so that if the centre of the turning is $\frac{7}{10}$ths of an inch under the axis of the bore, the workman, by the handles (*c*), lifts the slides, and of course the gun, the required distance. *g* are the bolts for fastening the saddles on the bed when the gun is brought to its proper position. D D are the turning frames, bolted to the large bed (A); they are set at right angles to the bed (B), and the spindles of the two frames are in a perfectly straight line.

The driving-shaft (E) goes through the inside of the bed (A) and under the centre of the turning-frames; on the driving-shaft there are keyed two pinions which gear into the wheels (F). There are openings in the top of the bed (A), through which the teeth get in contact; *h* are sockets of gun-metal, on which are keyed the wheels (F); *i* are the bearings in which the spindle (G) runs. H are the frames in which the turning tools are fixed; *k k* are the tools shewn with a cut; the pieces (*m*) on the other side are rubbers, which act as a stay to the tool, and to prevent tremor.

A groove is cut along part of the spindle (G), in which fits a corresponding key

fastened in the socket (*h*), so that the rotation of the wheel and socket gives a motion to the spindle, while the groove in the spindle allows it to move endwise, as may be required: the motion for feeding the cut may be wrought self-acting or by hand. J is the self-acting feeding motion, shewn in gear: to throw it out of gear, and work by hand, it is only necessary to push the wheel (*o*) back to the head of the stud (*g*), and turn the handle. The manner in which the self-acting motion is produced is very ingenious. The end of the spindle (G), which is farthest from the turning tool, is bored out hollow; into the tube there is fitted a spring, with four arms that force outwards: this spring is keyed on the end of a small steel shaft, having a small steel pinion on its other end: this pinion gears into the wheel (*o*), which, by the long pinion keyed on its boss, gives a motion to the wheel (*r*). The wheel (*r*) is keyed on the end of a screw, which is connected to the spindle (G), and so gives it the forward motion. One great advantage of having the motion through the spring is, that when the tool comes to any place on the trunnion where it cannot get forward, the spring slips in the tube, and no mischief arises.

As was observed before, to disengage the self-acting motion, it is only pushing the wheel (*o*) out of gear with the steel pinion on the end of the spring-shaft; and as the pinion on the boss of the wheel (*o*) is double the breadth of the wheel (*r*), it still remains in gear with *r*; so that the hand-wheel (*o*) retains a command over the spindle. K is a fly-wheel on the end of the driving-shaft (E), by which the workman may turn the tool round by hand, when he requires to do so. L is the strap-lever, by which the machine is thrown out or into gear: it is wrought by the handles (*n*). M are the fast and loose pulleys.

Before putting a gun into this machine, the workman divides off the distance of the centre of one of the trunnions from the base-ring, and then describes a circle. The gun is placed between the centre and cone. The gun is adjusted with a spirit-level. He knows by the drawing how much the axes of the trunnions are below the axis of the bore; so that by the handles (*c*) he raises the gun, setting it to the index as the gun requires: he then fixes a scriber where the turning tool is fastened, and by turning it round carefully by hand, he sees if the line it makes coincides with his former division; if it does not, the gun is shifted by the handles (*b*) until it is brought to its true position. The fastening bolts (*g*) are then tightened, and to prevent the gun from moving during the operation, it is wedged up underneath.

Both trunnions can be turned at the same time, the whole operation occupying from five to seven hours.

Nothing can exceed the accuracy by which guns are trunnioned with this machine. As the spindles are at right angles to a line drawn through the centre of the gun, the trunnions must be at right angles to the bore; and as the axes of the spindles are in a straight line, the axes of the trunnions must be in a straight line with one another.

When the guns are trunnioned, they are taken to the drilling machine to be vented.

Plate IV. shews side and front elevations of the drilling machine, with a section of the spindle: the same letters in all the figures apply to the same parts.

A is a strong frame of cast iron, in one casting; it is bolted to the wall of the building by the four bolts (*a*), with wall-plates on the outside. B are the fast and loose pulleys: on the same axle is keyed the cone pulley (C). D is a corresponding cone pulley, keyed on the same axle as the wheel (*b*). The object of having the cone pulley is to obtain variety of motion; for example, a hole of ¼ inch in diameter would be drilled with a much faster motion than a hole of 2 inches diameter. By having the cone pulleys, the workman may have the motion that best suits his work, by shifting the strap on the proper division of the pulley. S is the strap which connects the two pulleys; the wheel (*b*) gears with the wheel (*c*); the boss of *c* is fitted

into a socket or bearing (*d*), in the framing (A). In the spindle (*e*) which passes through the wheel (*c*) a longitudinal groove is cut: in this groove fits a key, which is fastened in the boss of the wheel (*c*) so that the rotation of the wheel gives a motion to the spindle, while the spindle is at liberty to slide up or down. The weight of the spindle is supported by a ball of cast iron (*f*), hung on the end of a chain (*g*) which passes over the pulley (*h*). The pressure to the drill is communicated by the fly-wheel handle (E). In the boss of the wheel (E) a screw is cut, through which passes a screw-socket (*i*), which fits upon the spindle. A groove is cut along the back of the screwed socket, in which fits a key, fastened in the framing (A), to prevent the screw from turning round, so that the turning of the fly-wheel (E) causes the screw to rise or fall; and as the screw (*i*) presses on the collar of the spindle (*e*), the screw and spindle rise or fall as the wheel (E) is turned, which is done by the hand of the workman: *k* is the apparatus for shifting the strap, from which are suspended the balls (*l*) by the cords (*m*) for throwing the machine out or into gear. The drill fits into a socket in the spindle at *n*.

We shall now describe the bed or frame in which the gun is laid in being drilled. The object of this machine is to afford accuracy and facility in placing the gun, in having the different holes drilled.

Plate V. gives a side elevation (fig. 1) of this machine, with part of the drilling machine above it. Figs. 2, 3, and 4, are different parts of the same: the same letters in all the figures apply to the same parts.

A is a bed of cast iron; the top surfaces are planed with dovetail edges; upon the bed are fitted the two slides or saddles (B and C). The slide (B) carries the body of the gun, while the breech rests upon C: each of these slides can be made to slide along the bed of the machine. Within the bed (A), and on each side of it, there is placed a horizontal screw, with a wheel (*a*) on the outer ends of them: into these gear other wheels (*b*), which are keyed on the boss of the fly-wheel handles (*c*). The screw passes through nuts in the slide. The handle and wheels seen in the drawing are for the slide (C), but those on the other side are exactly the same: by turning the handles (*c*) the slides pass along the bed as may be required.

On the slide (B) are two columns, working in transverse slides by the handles (*d*). The trunnions of the gun are laid into v's on the tops of the columns (see fig. 2). These v's are level, and at right angles to the spindle in the drilling machine; and as the trunnions are accurate and true (as was shewn before), a line drawn at right angles to the axes of the trunnions, from the highest point in the circumference of the gun, would bisect the bore. When the gun is laid in the v's, the first object is to find the highest point: this the workman readily does, by the aid of a spirit-level for the purpose. Both at the breech and muzzle a line is drawn, cutting the two points: upon this line he sets off the vent, and the hole for the tangent scale, and from it all other divisions in finishing the gun are taken. By the handles (*d*) of the transverse slides, this centre line is brought under the centre of the drill, and it now requires another kind of adjustment. Although the holes have to be perpendicular to the trunnions, they are not so to the gun lengthwise; but at the various angles for different patterns for guns, and in the same gun, the hole for the vent is at a different angle from the hole for the tangent scale: in drilling the former, the breech is raised above the muzzle, while in drilling the latter it often is under it. This is accomplished by the drilling-table (D), on the slide (C). The table is raised by the screw (*e*) underneath, working in a nut (*f*) in the slide (C). Near the top of the screw is keyed a bevel-wheel (*g*), in which gears a pinion, keyed on the same axle as the hand-wheel (*h*). At each end of the drill-table (fig. 3) there is a strong socket (*i*), accurately bored. These sockets slide up or down on the studs (*k*) that are fastened on

the slide (C). M is a v, fastened on the table, into which is laid the breech of the gun. A graduated plumb-level is applied to the muzzle, and the drill-table is raised or lowered by the handle (*h*) until the gun is lying at the right inclination. When this is done, the workman turns the handle (*c*) of the longitudinal screw, and brings the centre of the hole under the centre of the drill lengthwise. The gun is now right, and the hole is drilled; both operations, including adjusting and drilling, occupying a very short time indeed.

Besides the holes for the vent and tangent scales, in many guns there is a breeching loop at the cascable, in a line with the trunnions. In drilling this hole, the trunnions are taken out of the v's, and the gun is turned round until they are in a vertical position. The gun is then placed in wooden bearings in the frame (F), which is bolted to the slide (B). F is of cast iron, and planed on its bottom and front surfaces: on its front are planed two vertical dovetail slots, for the reception of bolts to fasten the frame (G), which slides up or down as may be required. The frame (G, fig. 4) is composed of two vertical studs (*m*) fastened on a roll-plate (*l*). On one of the studs the cross-head (H) swivels, with an opening in the boss; at the other end of the cross-head it clasps the other stud. K K are two pieces of wood that fit between the studs. To place a gun in the frame, the cross-head is turned to one side, the top piece of wood is lifted out, and the gun dropped into the other bottom piece: the top piece is again slipped in, the cross-head turned round to its place, and the gun bound by the screw and handle (L), when the gun is brought to a true level by the drill-table, and adjusted lengthwise as before, with the handle (*c*). It may be stated that the drill-table (D) can be used for ordinary drilling when not required for guns. The top surface is flat and level, and slots are provided to fasten the work by. (This machine was constructed in the establishment.)

When all the holes in the gun are drilled, it is taken out of the drilling-bed, and laid on a pair of trestles. The first thing done is to prepare the hole for the copper vent: this is accomplished by hand, with a series of screwing taps. The copper vents are made out of 1½-inch round bolt-copper. The pieces are cut off the bolt to the proper length by a circular saw, in a shaping machine. A number of the pieces are then fastened between two plates, on a planing machine, and have squares planed on one end of them; these squares fit into a chuck, in a small horizontal drilling machine. The other end of the copper runs in a steel bearing or collar. A boy holds a drill in his left hand, and with his other turns a screw that presses the drill into the metal. The hole is drilled right through. As the hole is small (⅜ths of an inch), the copper revolves at 770 revolutions per minute.

When as many pieces as are required are drilled, they are taken to a self-acting and screw-cutting lathe, to be turned and screwed: they are now ready for the gun. The vent is screwed into the hole by two men, with a powerful lever fitted on the square of the copper vent; and when the vent is home to its place, the square is cut off.

When six or eight guns are advanced thus far, they are again put in the boring and turning lathe, to have the projection of the copper cut off inside the bore, and to have the chamber finished.

Although the gun seems now almost completed, it is a striking fact, that as regards men's time, there has more to be bestowed upon it yet than in all the previous operations.

If we take for example a 24-pounder howitzer, for sea service: the cutting off the dead-head, centering, boring, turning, planing, trunnioning, drilling, and venting, will occupy altogether from seven to eight days; but the time that will be required to finish what is comparatively small,—the loop, vent-field, sight, and the neck of the trunnions,—will be from eight and a half to nine and a half days; while the expense

of tools, viz. chisels and files, is, to say the least, five times more than in all the previous operations. Six days more will be occupied in engraving the gun. The various parts that have to be removed and finished by the chisel and file are so very different in their shapes, that at first thought it would appear an impossibility to make a machine to do this work perfectly and efficiently; but on further reflection, these difficulties in a great measure vanish. A shaping machine for this very important purpose may be constructed, and we trust that before long this desideratum will be supplied.

JOHN ANDERSON.

APPENDIX.*

The Foundry of the Honourable East India Company for the manufacture of brass ordnance for India was originally established in Fort William, upon only a limited scale; the boring and turning of the machinery being worked by bullocks: but in 1826, Captain (now Lieut.-Col.) G. Hutchinson, of the Bengal Engineers, being appointed Superintendent and Director of the Foundry, he was permitted by the Government of India to return to England, with the view of obtaining new machinery for the establishment of the foundry upon a more enlarged and efficient footing. Accordingly, under the orders of the Honourable the Court of Directors, Captain Hutchinson submitted plans of machinery for the foundry to be worked by steam, prepared by Messrs. Hall and Sons, of Dartford, upon a much improved and self-acting principle of operation, to which Captain Hutchinson added the important improvement of effecting the accurate *turning* of the ordnance by means of the machinery, as well as the boring of the guns, by which a much greater degree of accuracy of metal is insured; also, after visiting the foundries abroad, he introduced some further improvements in the mode of turning the trunnions, and in the construction of a locomotive crane, by which a considerable expense was saved.

Previous to the removal to India of this beautiful and scientific machinery, executed with the greatest accuracy by Messrs. Hall and Sons, Captain Hutchinson had the honour of submitting plans of its principle of construction to the then Master-General of the Ordnance, Lord Beresford, who appointed a special committee of Artillery Officers to examine and report upon it. Captain Hutchinson met the committee at Messrs. Hall and Sons' Foundry at Dartford, and exhibited to them the great accuracy and celerity with which the new self-acting machinery executed the work, and especially the great importance of the arrangement by which the slide-rest (carrying the turning tool) turned with mathematical precision the outside of the gun, liable to be so inaccurately turned by hand. This principle, though differently executed, has now been introduced into the new machinery erected in the foundry at Woolwich.

Plate VI. shews the general plan of the new foundry of India, erected by Captain Hutchinson, near Calcutta, on his return with the machinery in 1829.

Plate VII. the plan of the self-acting principle of the lathes.

Plate VIII. shews an improved mode adopted in the construction of the reverberatory furnaces, by making the bottom of the furnace to ascend, instead of descending as usual from the fire-place: the flame being also thrown upon the metal more in the manner of a blow-pipe, the power of the furnace was greatly increased, half the usual time only being required to smelt the charge of the furnace.

Plate IX. Plan of a large syphon, 247 feet in length, and 5 inches interior diameter, cast and fixed by Captain Hutchinson, for the supply of water from a distant tank to the well in the foundry: a small pipe being attached to the air-

* By Lieut.-Colonel Hutchinson, F.R.S., Bengal Engineers.

CENTERING MACHINE.

Fig. 3.

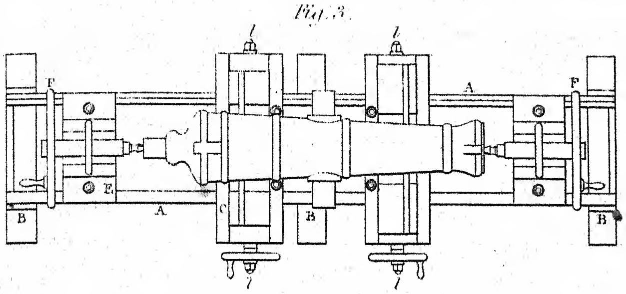


Fig. 4.

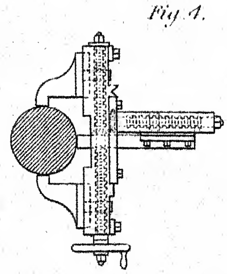


Fig. 2.

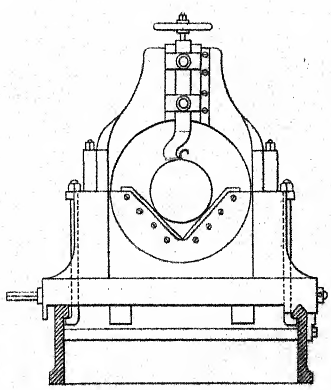


Fig. 1.

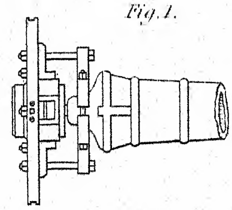
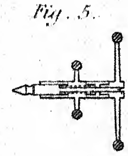


Fig. 5.



Taken from the 8th Vol. of Professional Papers.

J.W. Lowry fc.

London, John Weale, High Holborn, 1849.

BORING AND TURNING LATHE

Fig. 1.

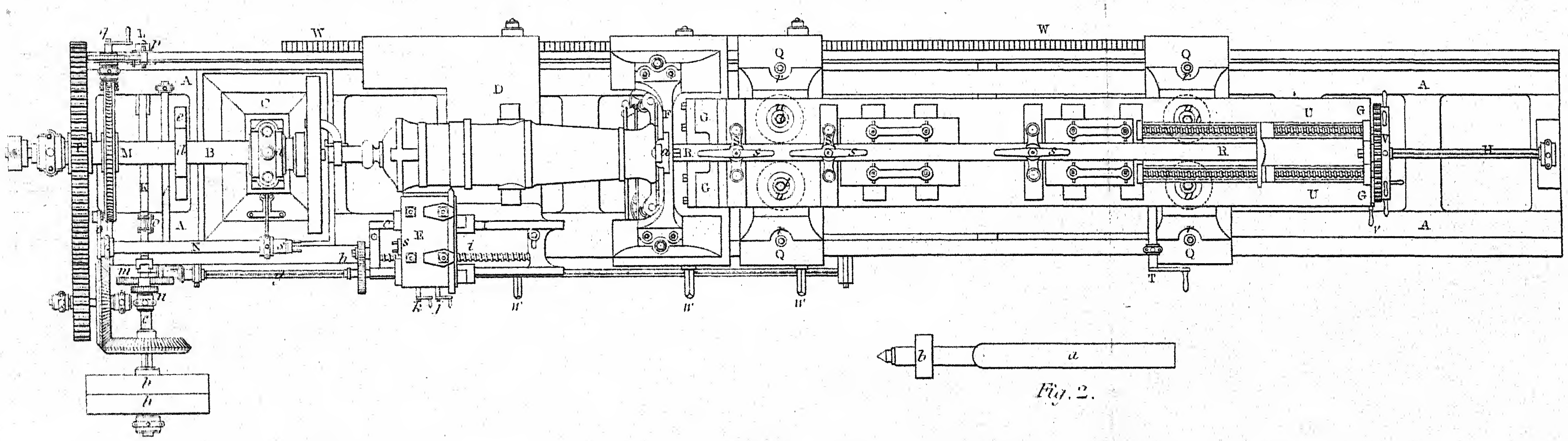


Fig. 2.

Inches 12 6 0 1 2 3 4 5 6 feet

Taken from the 8th Vol. of Professional Papers

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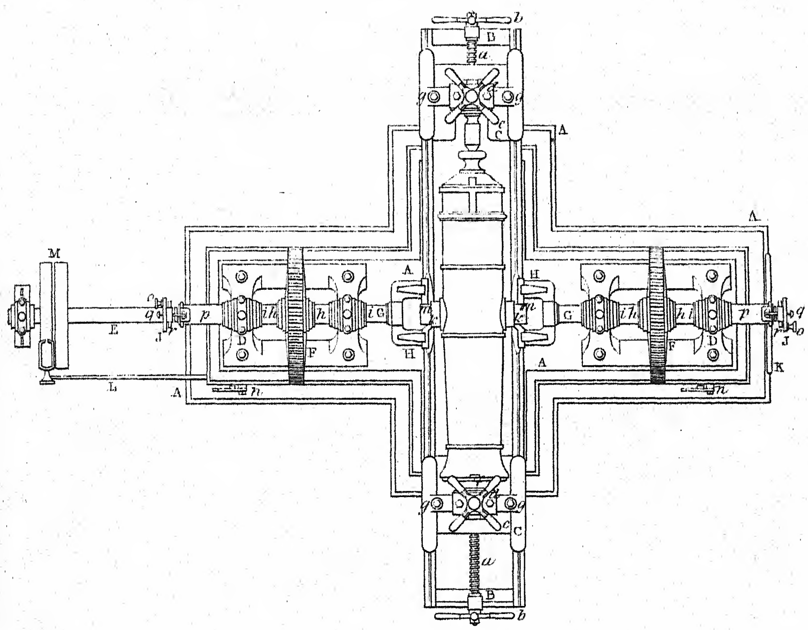
TRUNNIONING MACHINE



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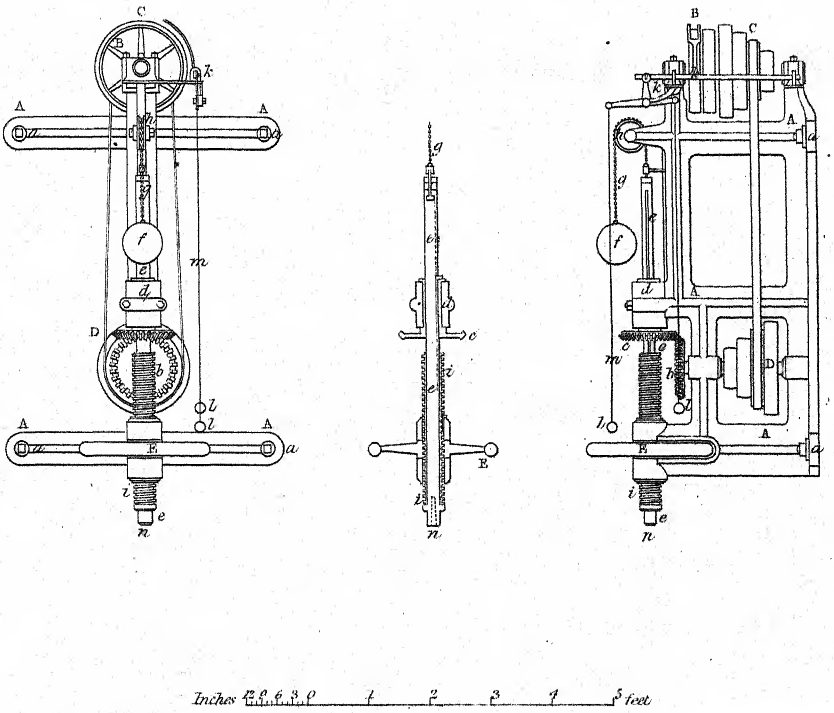
DRILLING MACHINE



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of Professional Papers

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BOUCHING FRAME.

Fig. 4.

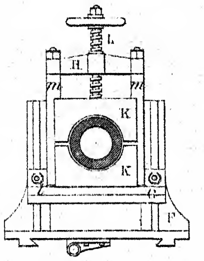


Fig. 3.

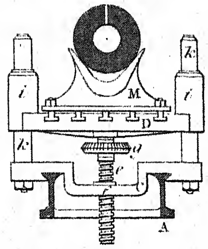


Fig. 2.

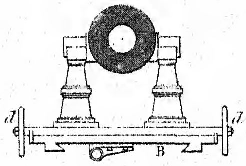
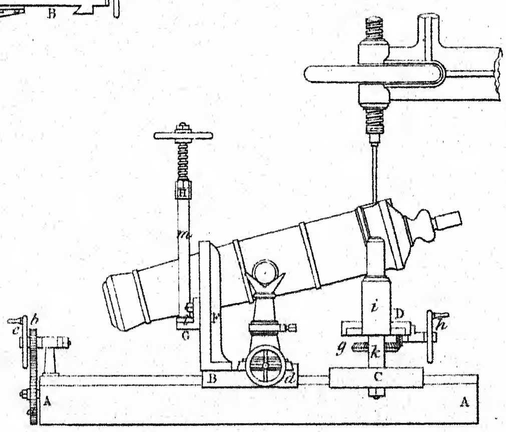


Fig. 1.



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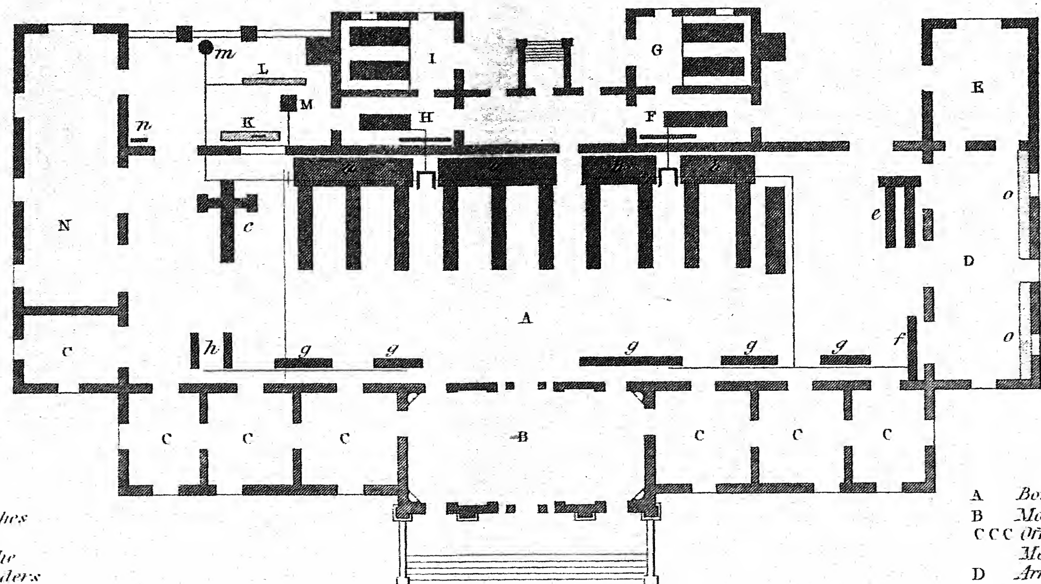
London, John Weale, High Holborn, 1849.

Appendix — Plate 6.



PLAN

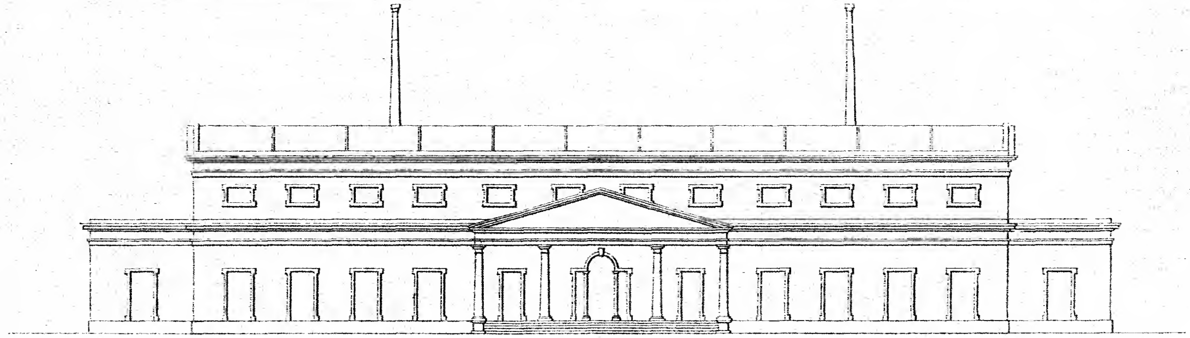
References.

- a a Six Gun Lathes
- b b Four Mortar Lathes
- c Trunnion Lathe
- d Dead Head Lathe
- e Lathes for Cylinders
- f Vertical Drilling Machine
- g g g Small Lathes
- h Elevating Screw Lathe
- m Loom Mill
- n Grind Stone
- o Vice Benches

References.

- A Boring Hall
- B Model Room
- C C C Office, Pattern and Metal Rooms
- D Armourers Room
- E Finishing Room
- F 12 Horse Steam Engine
- G Boiler Room
- H 10 Horse Steam Engine
- I Boiler Room
- K Circular Saw
- L Cross Cut Saw
- M Blowing Machine for Cupola for Casting Iron
- N Carpenters Room

G. Hutchinson F.R.S. Lt. Col. Bengal Engineers.



ELEVATION

PLAN & ELEVATION OF THE FOUNDRY FOR BRASS ORDNANCE &c.

AT COSSIPORE NEAR CALCUTTA

ERECTED IN 1834 BY

LT COLL HUTCHINSON F.R.S. BENGAL ENGINEERS

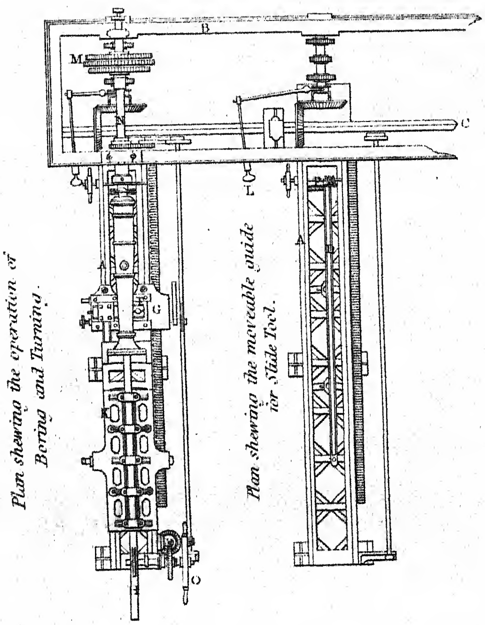
SUPT & DIRECTOR OF THE FOUNDRY.

J.W. Lowry fc.

Published by John Weale, 59 High Holborn, 1842.

Appendix I

Plan Section and Elevation of Lathe on an entirely new Self Acting Principle under the direction of Lt. Col. G.



REFERENCES

AAA *Boring Beds.*
B *Frame for carrying the Machinery for giving Motion to Mandrils.*
C *Shaft communicating with Steam Engine.*
D *Moveable Guide for Sliding Tool.*
E *Graduated Index for placing the moveable Guides at the required Angle.*
F *Slide attached to moveable Guide adapted to follow the taper of the Gun.*
G *Bed of Slide (F) with self traversing Motion adapted to moving parallel to the Axis of the Gun.*
H *Boring Bar; pressed forward by the Rack (I) moved by a pinion connected with the Self Acting Motion, or may be worked at pleasure by hand with the wheel O.*
I *Portion of Rack for propelling the Boring Bar other portions are fitted on at pleasure as the Bar enters the Gun.*
K *Carriage carrying the Boring Bar.*
L *Handle for throwing the Work in and out of Gear.*
M *Wheels for varying the speed of Mandril (N).*
P *Reverse Motion to Bed (G) added after the Machinery was put up.*
S *Also a friction Clutch † was fixed upon the upright Shaft (S) giving motion to the pinion propelling the Boring Bar, also a friction Clutch was attached to the Mandrils. N N.*
W *The Box Chucks T, at the end of the Mandrils N, were altered for the face Plate W which greatly expedited the adjustment of the Gun.*

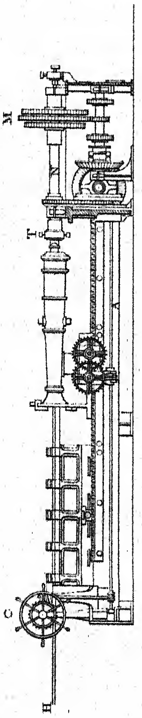
London, John Weale, 59, High Holborn, 1850.

Construction of Ordnance.

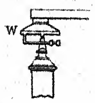
for Boring and Turning of Ordnance

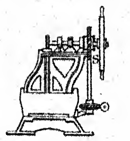
executed by Mefs.rs Hall and Sons, Dartford)

Hutchinson F.R.S. Bengal Engineers.

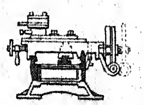


Elevation of Boring Lathe.





End View of Lathe.



Section of Boring Bed
Slide Rest and Moveable Guide.

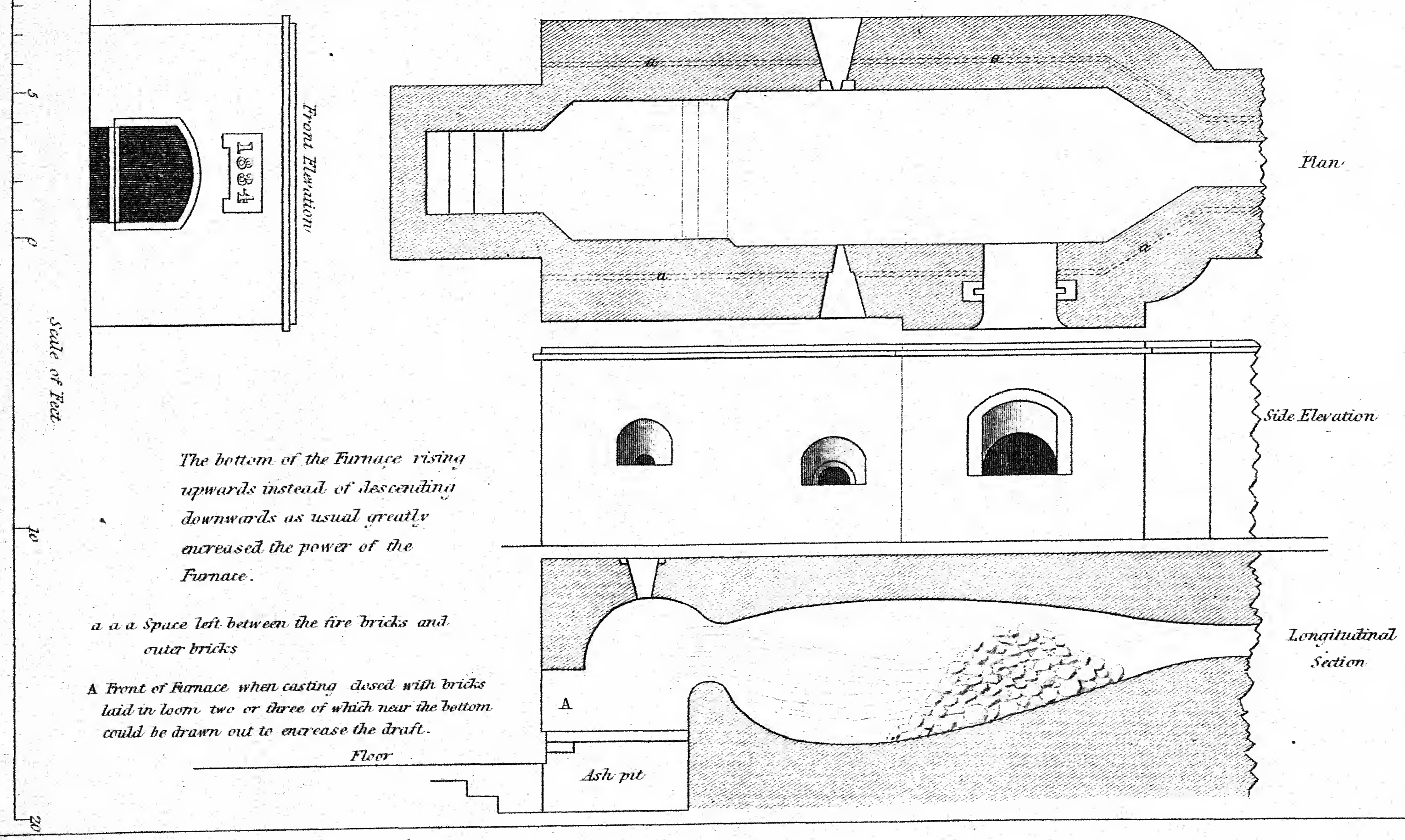
Inches 12 0 1 2 3 4 5 10 15 20 feet

N.B. The V Collars with steel facings were abandoned and Circular Collars suited to each Gun were found far preferable in diminishing the intensity of the heat generated by the friction.

J. W. Lowry fc.

Appendix —— *Ordnance, Construction of*

PLAN ELEVATION & SECTION OF ONE OF THE REVERBERATORY FURNACES IN THE FOUNDRY AT COSSIPORE

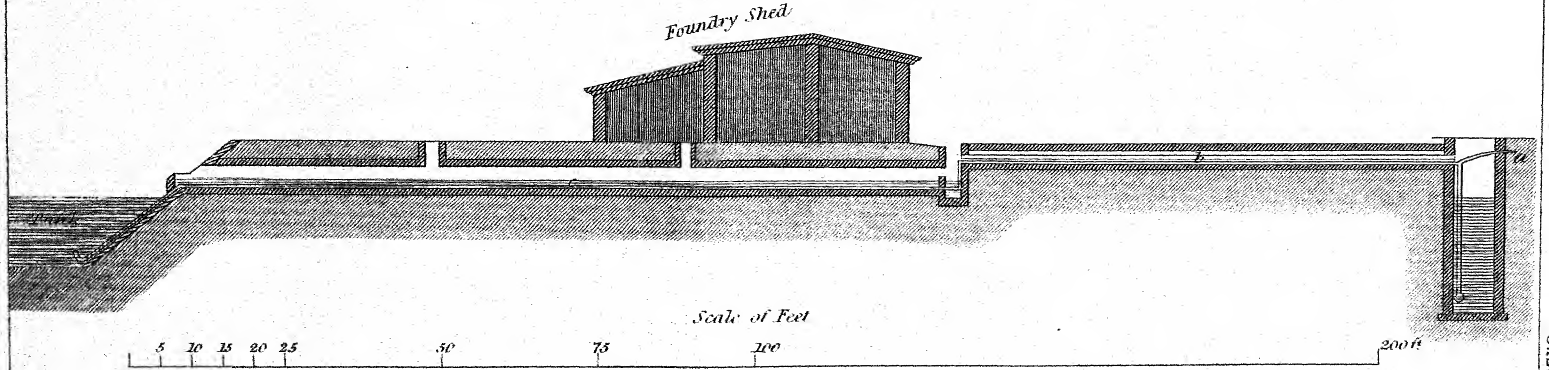


G. Hutchinson F.R.S. Lt. Col. Bengal Engineers. J. W. Lowry sc.

Published by John Weale High Holborn 1849.

Appendix *Ordnance, Construction of*

SYPHON LAID DOWN IN THE FOUNDRY YARD AT COSSIPORE.



Length of Syphon .... *247 feet*

Interior Diameter .... *5 inches*

Leg of Syphon in Wall ..... *22 feet*

a *Small pipe to the pump of the Engine*

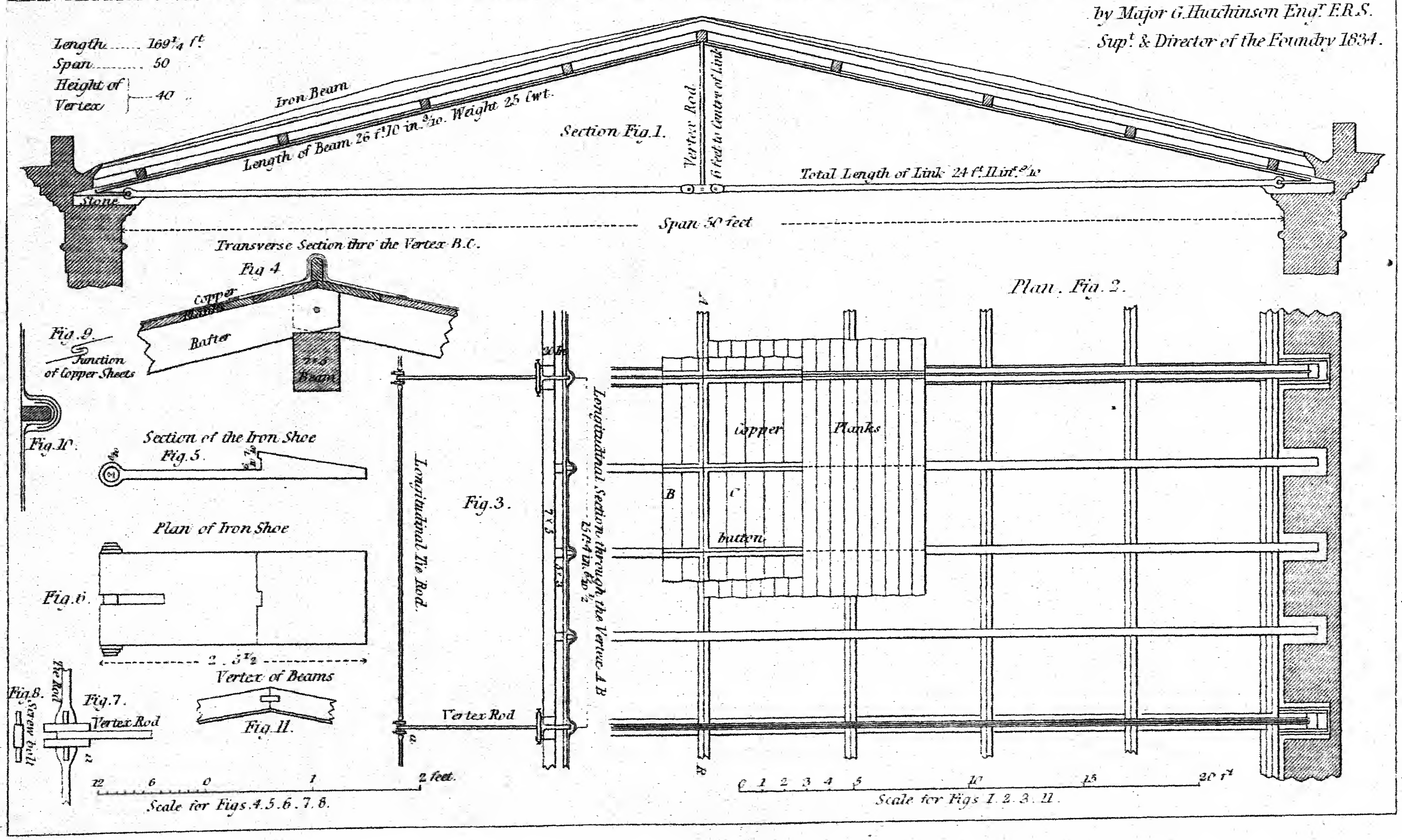
c b *Syphon covered with Water*

...tchinson F.R.S.Lt.Col.l Bengal Engineers. J.W. Lowry fc.

Published by John Weale High Holborn 1849.

PLAN SECTION &c. OF THE LARGE IRON TRUSSED ROOF CONSTRUCTED OVER THE BORING ROOM OF THE NEW GUN FOUNDRY AT COSSIPORE

by Major G. Hutchinson Engr. F.R.S.
Supt. & Director of the Foundry 1834.



J. W. Lowry fc.

London, John Weale, High Holborn, 1850.

pump of the steam engine, and the syphon kept under water by a small pipe from the overflow cistern, it was always found to work efficiently.

Plate X. Section of the iron trussed roof erected over the boring-hall, nearly 170 feet in length, 50 feet span, and 40 feet in height, the whole of which was put up and finished without any scaffolding from below.

Moulds.—The mode of making the ordnance moulds in India is in loam (a preparation of clay and cut rope), and not in sand, as usual in Europe. A model or pattern of the gun to be cast being turned in wood, (due allowance being made for the shrinkage of the metal,) along with the proper length of dead-head, the model is oiled over and a layer of loam spread over the upper half, about one inch thick, in which is embedded half-circular pieces of hoop-iron, placed about 4 or 5 inches apart: when dry, another layer of loam is put on with hoop-iron, embedded as before, together with longitudinal bars about $\frac{2}{10}$ths of an inch thick and one inch wide, placed 2 or 3 inches apart, running the whole length of the mould: when dry (the iron being covered with loam), the model is turned over, and the other half finished in the same manner: when the whole is perfectly dry, the two halves are separated, and the wooden model removed. The interior of the mould is then dressed and made perfectly smooth, and the two halves being joined together, are strongly hooped with iron, and covered with another layer of loam, which completes the mould. It is then removed, when dry, to the casting-pit, and burnt red-hot, and before it is cool the metal is run into it.

The new foundry, when completed, was found capable of executing with the greatest accuracy any description of machinery required, as well as the preparation of the ordnance; and such was the efficiency of the improvements introduced, that Lieut.-Col. Hutchinson was able very greatly to reduce the cost of casting and turning the ordnance for India, whilst the important desideratum of perfect uniformity was established throughout all the Presidencies.

ORDNANCE DEPARTMENT:

1. A branch of the War Department of the British Empire, instituted for the supply of all warlike stores used in the Naval and Military Services. According to Haydn's 'Dictionary of Dates,' the first Master of the Ordnance was created in Henry the Eighth's reign; and probably the Tower of London was the original dépôt of arms and military stores. Kane's 'List of Officers of the Royal Artillery' gives Robert, Earl of Essex, as the first Master-General, in 1596.

2. An Ordnance Department is not peculiar to this country, as the Government of the United States of America has a similar establishment, forming a part of its War Department, for the supply of military stores.

3. It does not appear that the Ordnance Department of this kingdom became especially military until the early part of the eighteenth century, after the organization of the Royal Artillery in 1743, under the Duke of Montague as Master-General: previous to this, the duties were confined to the supply of cannon, ammunition, and stores to the Navy and Army.

4. From this time the Ordnance Department was administered by the Master-General and Board, the latter being composed of a

Lieutenant-General of the Ordnance,
Surveyor-General,
Clerk of the Ordnance,
Principal Storekeeper,

Clerk of the Deliveries, and
Treasurer;

the Lieutenant-General presiding at the Board, and who assisted the Master-General in his military capacity, and acted for him in his absence.

This appointment, and those of the two last officers of the Board, have been suppressed. After the Peace of 1763, the Engineer Corps was formed, when the Ordnance Department became a Constructive Board, with charge of all forts and fortresses, and directed the construction of all the fortifications and military storehouses and barracks for the Ordnance Corps.

5. Charles, Duke of Richmond, as Master-General from 1782 to 1795, consolidated and regulated the duties of the Ordnance, and organized a Board of Officers, called Respective Officers, representing the Master-General and Board at every permanent station in the empire, to maintain the regulations of the Department, and to secure a joint responsibility in the expenditure of money and stores. This Board is composed of the

Commanding Officer of Artillery,
Commanding Engineer, and
Storekeeper.

The orders framed by that distinguished man of business are the basis for the management of the Ordnance to this day, at home and abroad.

6. At the end of the 18th century, the Survey of Great Britain was placed under the direction of the Ordnance, and a corps of Surveyors and Draughtsmen formed, to assist in this operation; so that at the close of the War the duties of the Department had been increased from the mere provision, custody, and supply of warlike stores to the Sea and Land Service, to the construction and maintenance of fortifications, magazines, storehouses, and military buildings, in the United Kingdom and the Colonies, the entire government of the Royal Regiment of Artillery, the Corps of Royal Engineers and Sappers and Miners, the Survey of Great Britain, and the provision of ordnance, shot and shells, &c., for the Service of the East India Company. (See Appendix.)

7. When the War finally terminated in 1818, by the withdrawal of the army of occupation from France, and the Duke of Wellington became Master-General, his Grace's attention was directed to a reduction of the Ordnance Department, suited to the prospect of a long Peace, and the consolidation of others with it, which led to the amalgamation of the Barrack Department with the Ordnance, the extension of the Survey to Ireland, and the transfer of the store branch of the Commissariat (including the Quarter-Master-General, stores of camp equipage of the army for the field); and the Board of Ordnance was reduced to the following establishment:

The Master-General, *with a Military Secretary,*

With a *Civil Secretary,* { The Surveyor-General, / The Clerk of the Ordnance, / The Principal Storekeeper, } *Forming the Board,*

dividing the duties of the	Personel,	under the	Master-General,
"	Materiel,	"	Principal Storekeeper,
"	Finance,	"	Clerk of the Ordnance,
"	Audit of Expenditure of money and stores,	"	Surveyor-General.

8. The Ordnance expenditure for the year 1849 was estimated at £2,654,275, and divided as follows:

Administration, *at home and abroad*	£ 401,259
Personel; the expense of Ordnance Military Corps . .	711,895
Materiel; Ordnance, Barrack, and Military Stores .	625,068
Construction of Fortifications, Barracks, &c. . . .	649,535
Scientific Branch; Surveys and Estimates	94,859
Non-effective; Half-pay and Pensions	171,659
	£ 2,654,275

G. G. L.

APPENDIX.*

Copy of Warrant of Queen Victoria to the Master-General of the Ordnance.

Victoria R.—Right trusty and well-beloved Councillor, We greet you well. Whereas King Charles the Second and King James the Second did make an establishment of the Office of Ordnance, in a book entitled Instructions for the Government of Our Ordnance, under Our Master-General thereof, committed to five principal Officers, and signed by the said King Charles and King James, and the Principal Secretaries of State, which were confirmed by his Majesty King William, her Majesty Queen Anne, his Majesty King George the First, his Majesty King George the Second, his Majesty King George the Third, his Majesty King George the Fourth, and his late Majesty King William the Fourth, Our Royal Predecessor:

Our will and pleasure and express command is, that all orders, warrants, and instructions or directions therein contained and given by the said King Charles and King James aforesaid, together with the additional instructions made by his Majesty King George the Second, his Majesty King George the Third, his Majesty King George the Fourth, and his late Majesty King William the Fourth, shall continue in force to be obeyed and observed by all and every person or persons who in Our said office are or shall be concerned, as fully and amply as the same were or ought to be observed in the reigns of the said King Charles, King James, King William, Queen Anne, King George the First, King George the Second, King George the Third, King George the Fourth, and his late Majesty King William the Fourth, and for your so doing this shall be your sufficient warrant until Our further pleasure be known. Given at Our Court at St. James's, this 18th day of June, 1839, in the second year of Our reign.

By Her Majesty's command, (signed) J. Russell.

To Our right trusty and well-beloved Councillor,
Lieutenant-General Sir Richard Hussey Vivian, Bart., G.C.B. and G.C.H.,
Master-General of Our Ordnance.

Copy of the Patent of the Master-General of the Ordnance.

Victoria, by the Grace of God, of the United Kingdom of Great Britain and Ireland, Queen, Defender of the Faith; To all to whom these presents shall come, greeting. Whereas We did, by Our letters patent under the Great Seal of Our United Kingdom of Great Britain and Ireland, bearing date at Westminster the 13th day of September, in the fifth year of Our reign, give and grant unto Our right trusty and well-beloved Councillor, Sir George Murray, Knight Grand Cross of the Most Honourable Military Order of the Bath, Lieutenant-General in Our Army, the Office of Master-General, as well of all and all manner of Our ordnance as of Our arms, armouries, and other habiliments of war within Our said United Kingdom, to have, hold, enjoy, occupy, and exercise the office aforesaid to the said Sir George Murray, by himself, or by his sufficient deputy or deputies, during Our pleasure, as by the same letters patent (relation being thereunto had) may more fully and at large appear. Now know ye, that We have revoked and determined, and by these presents do revoke and determine the said recited letters patent, and all and singular matters

* From the second Report of the Select Committee on Army and Ordnance Expenditure.

and things therein contained. And further know ye, that We, very much confiding in the prudence and wise circumspection of Our right trusty and entirely beloved cousin and councillor, Henry William Marquis of Anglesey, Knight of the Most Noble Order of the Garter, Knight Grand Cross of the Most Honourable Order of the Bath, and General in Our Army; and for divers good causes and considerations Us hereunto especially moving, of Our especial grace, certain knowledge, and mere motion, have given and granted, and by these presents do give and grant unto the said Henry William Marquis of Anglesey the said office of Master-General as well of all and all manner of Our ordnance as of Our arms, armouries, and other habiliments of war within Our said United Kingdom of Great Britain and Ireland, and him the said Henry William Marquis of Anglesey, Master-General as well of Our ordnance as of Our arms, armouries, and other habiliments of war within Our said United Kingdom, We do make, ordain, and constitute by these presents, to have, hold, enjoy, occupy, and exercise the office aforesaid to him the said Henry William Marquis of Anglesey, by himself, or by his sufficient deputy or deputies, during Our pleasure, together with all and singular the salaries, allowances, rights, profits, emoluments, and advantages whatsoever to the office aforesaid in any manner belonging or appertaining, and in as ample manner and form to all intents and purposes whatsoever as the said Sir George Murray hath had, held, received, or enjoyed, or ought to have had, held, received, or enjoyed. We will also, and by these presents command and direct all and singular Our officers and ministers of Our arms and armouries aforesaid, and all and every of them, that they from time to time, and at all times hereafter, be and shall be subject and obedient to and governed by the said Master-General of Our ordnance and armouries aforesaid within Our said United Kingdom for the time being. And further, We will and grant that these Our letters patent, or the inrolment thereof, shall and may be good, firm, valid, sufficient, and effectual in the law, as well in all Our courts of record as elsewhere, notwithstanding the ill-reciting, or not certain or fully reciting the said recited letters patent, or the date thereof, or any other omission, imperfection, defect, matter, cause, or thing whatsoever to the contrary thereof in anywise notwithstanding. In witness whereof We have caused these Our letters to be made patent. Witness Ourself at Our Palace at Westminster, this 14th day of July, in the 10th year of Our reign.

By writ of Privy Seal, (signed) EDMUNDS.

The Ordnance Department is charged with the following duties:

The provision, custody, and supply of every description of warlike stores, whether for Sea or Land Service; ordnance, carriages, small arms, ammunition, pontoons, tents, and camp equipage, intrenching tools, every thing, in short, which is required to arm a fleet or fortress, or to equip an army for the field.

The construction and maintenance of fortifications, magazines, storehouses, military prisons and buildings of every description in the United Kingdom and the Colonies.

The survey of the United Kingdom.

The entire government of the Royal Regiment of Artillery, the Corps of Royal Engineers and Sappers and Miners, including their preliminary education, their formation, instruction, pay, allowances, clothing, equipment, and military discipline.

The appointment and promotion of the Officers, their claims to retirement, the claims of their widows and children to pensions.

The construction, maintenance, and charge of the barracks in Great Britain and Ireland; with the provision and issue of barrack stores for the troops occupying them. This duty was transferred to the Ordnance in 1822, having previously formed the business of two large separate establishments.

Also, the barracks and military buildings in the Colonies, transferred from the Army Extraordinaries and Colonial Department.

1822. 1826. Transferred in 1822. The business formerly belonging to the Commissariat Store Branch of the Treasury and the Storekeeper-General, comprising the clothing and accoutrements of all colonial corps (six regiments) which are not provided by their Colonels; also arms, clothing, and accoutrements for military pensioners, the constabulary and revenue police in Ireland, and the militia in the Colonies.

Great coats for the whole Army; and the various miscellaneous supplies for convict and colonial services.*

The supplies of bread, meat, and forage for the army in Great Britain and the Channel Islands,† and the supply of oats, fuel, and light for the Commissariat in the Colonies.

The provision of ordnance, shot and shells, &c., for the Service of the East India Company, which are paid for by that department.

With respect to the mode in which the stores are obtained, some are manufactured within the department, as brass ordnance, carriages, rockets, ammunition and laboratory stores, a portion of the small arms, part of the gunpowder. The rest are obtained by contract, open to competition; the supplies all undergoing rigid professional examination.

The issues for the Navy are made upon the requisitions of the Admiralty; the different natures of guns or stores are discussed, when necessary, between the two departments; new inventions are submitted to joint committees; and thus the science and experience of each Service are made available for the other, and an unity of equipment, in all things practicable, is preserved.

In like manner, the supplies of arms‡ and ammunition for the Army are made on requisitions from the Commander-in-Chief.

Those for clothing for colonial corps, clothing and stores for military prisons, and great coats for the army, on requisitions from the Secretary at War; and those for various other stores, on requisitions from the Secretaries of State, and the Irish Government.

The patterns of arms, &c., are selected in concert with the Commander-in-Chief.

Dated 25 August, 1838. The equipment of the artillery, the armament of works, and all matters of this nature, are decided by the Master-General on reports from the heads of departments.

The barrack branch of the establishment is governed by regulations approved by the Treasury, and embodied in a Royal warrant. With respect to the movement of troops, and the occupation of barracks, the Quarter-Master-General is the channel of communication with this department, as he is also in case of any differences or discussions with the troops, which must occasionally arise in the endeavour to check unauthorized or unnecessary expense. On questions relating to the defences, the barracks, and other buildings in the Colonies, the Ordnance is in constant communication with the Secretary of State for the Colonial Department.

For the performance of its various duties, and the care of the extensive property vested in it, the Ordnance Department necessarily has establishments in every part of the empire; but these are kept as low as possible. Whenever practicable, the duty of Barrack-Master is combined with that of Storekeeper.

For the purposes of general control, the Commanding Officer of Artillery and the Commanding Royal Engineer are associated with the Storekeeper at each station, under

* The claims for these services, in 1847-8, amounted to £270,000.

† England, from 1st July, 1834; Ireland, from 1st July, 1837; re-transferred to the Commissariat, 1st July, 1847.

‡ Although arms are supplied on the requisitions of the Commander-in-Chief, each issue is, according to an old form of office, sanctioned by a Royal warrant, obtained in the following manner: the Secretary at War, on a communication from the Commander-in-Chief, applies to the Secretary of State for the Home Department, who obtains Her Majesty's signature, and sends the warrant to the Ordnance.

the denomination of 'the Respective Officers,' who correspond directly with the Board of Ordnance. The military Officers are a check upon the Storekeeper in his periodical demands for money, before transmitting which he is obliged to produce to them not only his accounts, but the actual cash in hand; and the united body is found most useful, especially in the Colonies, in maintaining the Ordnance regulations, the object of which is to prevent as much as possible unauthorized expenditure, whether by Governors, Commanding Officers, or other local functionaries.

The general expenditure, under its several heads, is duly controlled by the Treasury, whilst the Board of Ordnance exercises the utmost vigilance in its detailed appropriation; and it may be stated that, being to a certain extent independent of the Naval and Military authorities, the department is enabled to check expenses both for equipments and works in a manner which would be impracticable under a different organization.

The powers of the Master-General are thus described in the twenty-first Report of the Select Committee on Finance, 19th July, 1797:

"The Master-General, who, in his military character, is Commander-in-Chief over the Artillery and Engineers, has, in his civil capacity, the entire control over the whole of the Ordnance Department; he can alone do any act which can otherwise, if he does not interpose, be done by the Board; he can order the issue of money, but that order must be executed in the usual mode by three* Board Officers."

In practice, however, the business which the Master-General takes upon himself, independently of the Board, is chiefly military; questions of military discipline and promotion, the selection of Officers for particular duties, the distribution of the Ordnance corps (in communication with the Commander-in-Chief and the Secretaries of State), the government of the Royal Military Academy, the investigation (through the select committee at Woolwich) of military inventions and improvements: to him also belong all appointments and promotions in the civil department, excepting only those of the clerks at the Tower, which rest with the several Officers of the Board.

But the great mass of business of a mixed or civil nature, every thing of importance connected with finance, is performed by the Master-General and Board jointly; and whatever orders are given by the Board, without previous reference to the Master-General, he is made acquainted with by the minutes recording their proceedings being sent to him.

The above statement will show the nature and extent of the business which comes before the Master-General and Board of Ordnance for their decision, the correspondence relating to which is carried on in their offices in Pall Mall.

18th June, 1849. (Signed) GEORGE ANSON.

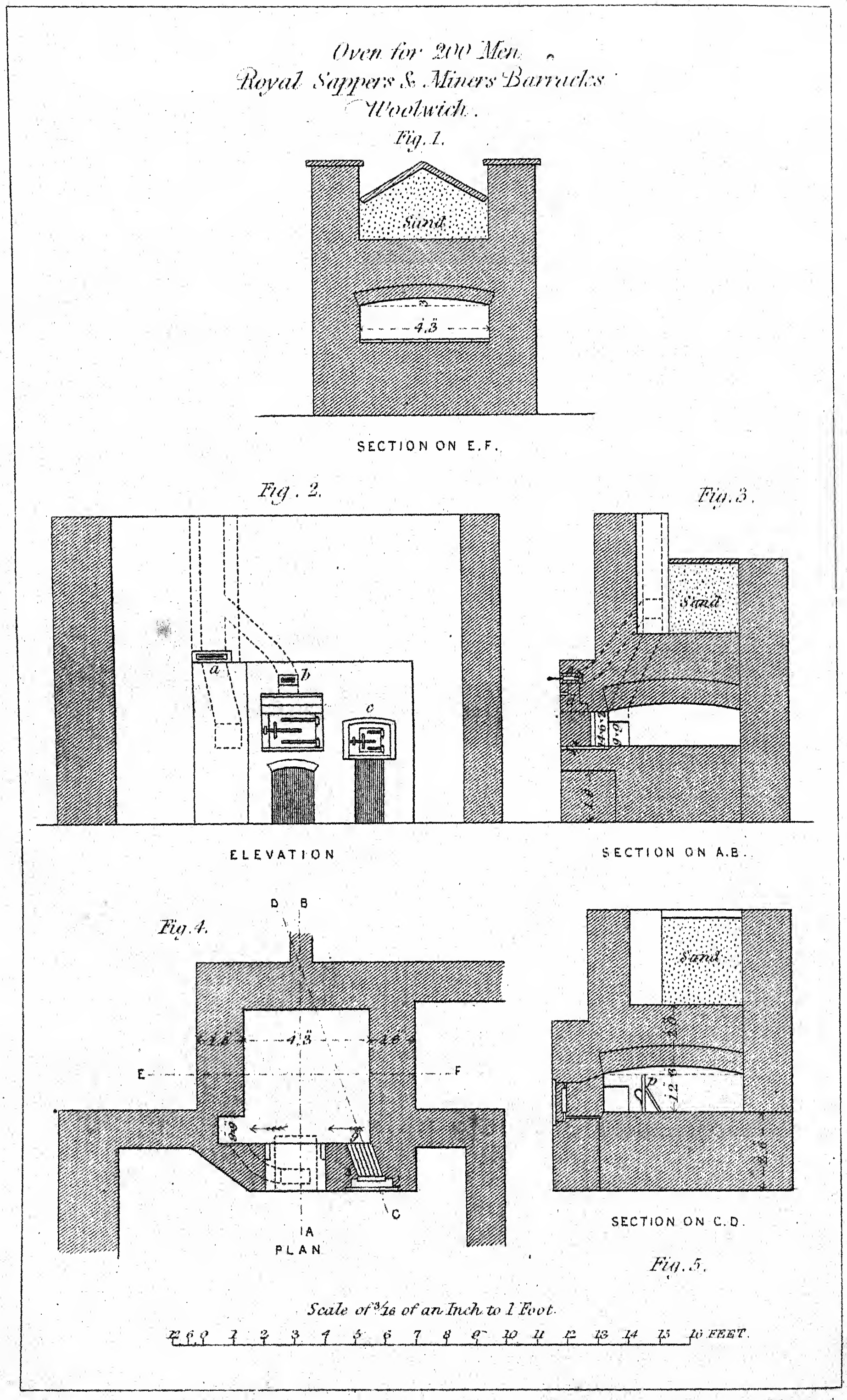
OVEN, FIELD.†—For camps or temporary purposes, an oven may be constructed of clay formed into an arch over a rough temporary frame or 'centre' of boards, and supported on a strong wooden or stone pier, so that the hearth may be about 3 feet above the ground, for convenience in putting in the bread; but by making an excavation in front for the same purpose, it may be placed on the level of the ground.

The floor or hearth should be formed of brick, stone, or clay tempered and well rammed.

Sun-burnt bricks or sods cut into the form of arch-stones may likewise be used for the upper part or roof; and if iron bars can be obtained, they may be used to support it; also logs or fascines well plastered with clay. A doorway is made in the front wall, and also an opening in the upper part of the farther end, for the smoke

* The number of the Board being now reduced to three, the signature of one of them, with the counter-signature of the secretary and a chief clerk, is sufficient.

† By Capt. Bainbrigge, R. E.



T. Nugent 2nd Corpl. R.S. & M.

J. W. Lowry fc.

London, John Weale, 59, High Holborn, 1850.

to escape by during the heating, both of which must be perfectly closed during the baking, when the temperature must be at least 250° Fahr. at the beginning, and 170° at the close. An oven should not be made to contain more than 500 rations, because it takes ten minutes to place that number in it; and more than ten minutes' difference of baking spoils the bread.

For every 100 rations a superficies of hearth of 30 square feet is required, and the height inside should be about 18 inches.

Travelling ovens of iron have sometimes been used, but the advantage of having the means of baking thus always at hand is considered to be more than counterbalanced by their requiring a great number of horses for their transport.

Kneading troughs are made by digging trenches in a dry spot, 2½ feet deep, for the bakers to kneel in; and parallel to them, with an interval of a foot, smaller trenches 1 foot deep, for the dough, having their sides ~~levelled~~ lined with planks, which should be dried by fires of chips; and the dough must be surrounded with dry branches, to insure its rising.

OVEN, PERMANENT.*

OVEN FOR 200 MEN, ROYAL SAPPERS AND MINERS' BARRACKS, WOOLWICH.

The oven shewn in the accompanying Plate requires half a bushel of coals to heat it sufficiently for all the ordinary purposes of baking for the soldiers' messes. The time necessary for this purpose is three hours. It is the practice to throw a small quantity of saw-dust into the oven, to hasten the process of heating it, and to burn away the small quantity of soot that accumulates on the top of the oven. (See Plate.)

The arrangement of the flues is explained by the dotted lines: that marked *a*, in the elevation, is the main flue, into which *b* is conducted, for the double purpose of creating a draught and carrying off the hot air and steam when drawing from the oven. (Fig. 2.)

It is suggested by private Thomas Cliff, Royal Sappers and Miners, an experienced cook, in charge of the oven, that it would be much improved by adopting the arrangement of the flues which he has seen in Commissariat ovens at Bermuda.

He would suppress damper *b*, which is seldom, if ever, used, reducing the throat of that flue at *d* (in section) to about 2 inches in width, but extending the whole width of the oven door. (Figs. 2 and 3.)

He would also have a flue from the furnace to run into the main flue, with a damper at C (in elevation): thus, by cutting off the fire in the furnace from the oven by a loose plate (*p*), and by opening the damper at C, the smoke, &c. would ascend by that flue; and it would be unnecessary to rake out the fire from the furnace for each baking, as is now the case. (Figs. 4 and 5.)

PAH.†—The strength of the Pahs of New Zealand consists principally in the choice of position.

They are generally situated on peninsular points, with three sides inaccessible, being steeply scarped towards the sea, usually from 50 to 60 feet in height, and palisaded at top: the depth of water round them is such as to prevent any vessel larger than those of 6 or 8 tons burden approaching them within the range of field guns; the attack of three sides, except by surprise, being impracticable; and the fourth side is always cut off by a deep ditch having steep scarps from 20 to 30 feet in height, and counterscarps from 6 to 16 feet. The nature of the soil, being generally a stiff clay or soft sandstone, retains the slope of 60 degrees.

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* By Lieut. Ross, R. E., Acting Adjutant R. S. and M.

† By the late Captain Bennett, R. E.

The terreplein, from 20 to 30 feet broad, has a strong palisade in front, as shewn in Plate II., or upon the parapet and banquette, as in Plate I., fig. 2; and the whole of the interior of the pah is intersected in every direction by fences: the ditches are frequently flanked by a strong palisade. In addition to the principal pah, there is also frequently an outer work with a low ditch palisaded in front, and commanded by the main work (Plate III., figs. 5 and 10); and should one part of the pah be considered weaker than another, it is strengthened by a double palisade 2 feet wide (fig. 9), with embrasures, and a trench to afford cover. Pahs are sometimes strengthened by three rows of palisades, as shewn in section, fig. 13, Plate IV.

The palisades themselves consist of large trees about one foot in diameter, roughly hewn; they are from 12 to 20 feet in height, rudely ornamented at top: between these, long stakes from 8 to 10 feet high, and 1½ inch in diameter, and tangent to each other, are strongly bound together, as in figs. 6, 7, and 8, and sometimes rough three-sided stakes, about 9 inches in diameter, are used.

Should the pah not be situated on a peninsula, its front consists of one steep side towards the sea, with generally a deep and wide gully on each flank, and the gorge is protected by a deep ditch, as before described.

The sections of the Pahs of Motua, Tapû, Otumaiti, and Tamutu, will be sufficient to exemplify the usual defences, but the natives of New Zealand evince considerable military knowledge.

The number of men the pahs could contain varies from 300 to 800, and they contain a large supply of provisions in holes excavated for the purpose: the men are well armed with muskets, and well supplied with ammunition, and they use the tomahawk for close quarters.

The choice of position relates to that arm against which they have hitherto had to contend with, viz. the musket; and as they are generally commanded from 200 to 600 yards, they are open to destruction from light shells and carcasses; but without artillery the attack of a strong pah may be attended with considerable loss to the assailant.

Note.—Description of Heki's Pah, in New Zealand, by Major Marlow, Royal Engineers, Plate IV.

The dotted lines denote rows of fences composed of trees deeply sunk in the ground, between 9 and 15 inches thick, bound close together by a strong native line or rope at the top and bottom: upon the outer row of trees a screen between 4 and 6 inches thick, and 8 and 9 feet high, was formed from a native plant called the New Zealand flax, which is exceedingly tough, and at a distance capable of resisting a musket-ball.

This screen was kept about 18 inches above the ground, to serve as loopholes to fire through from the trench marked T T, Plate IV., figs. 13 and 14; S S serving as traverses.

PALANQUES.—According to Bousmard, Palanques were small intrenched camps, used by the Turks in their irruptions into Europe, to secure their conquests, and as strongholds for their families and plunder, and were capable of containing a garrison of from 700 to 4000 men.

The construction of these forts or fortified posts was generally of timber, of a rude nature, similar to the *pah* of the New Zealanders.*

* "Les hyppas sont des enceinte de troncs d'arbres jointifs, plantés avec quelque inclinaison vers l'intérieur de l'espace renfermé; en sorte que les défenseurs placés sur des plateformes, ou échafauds éléves intérieurement, de distance en distance, et surtout aux angles de l'enceinte, découvrent parfaitement à l'extérieur le pied de ces troncs d'arbres."—*Essai Général des Fortifications. Discours Préliminaire.*

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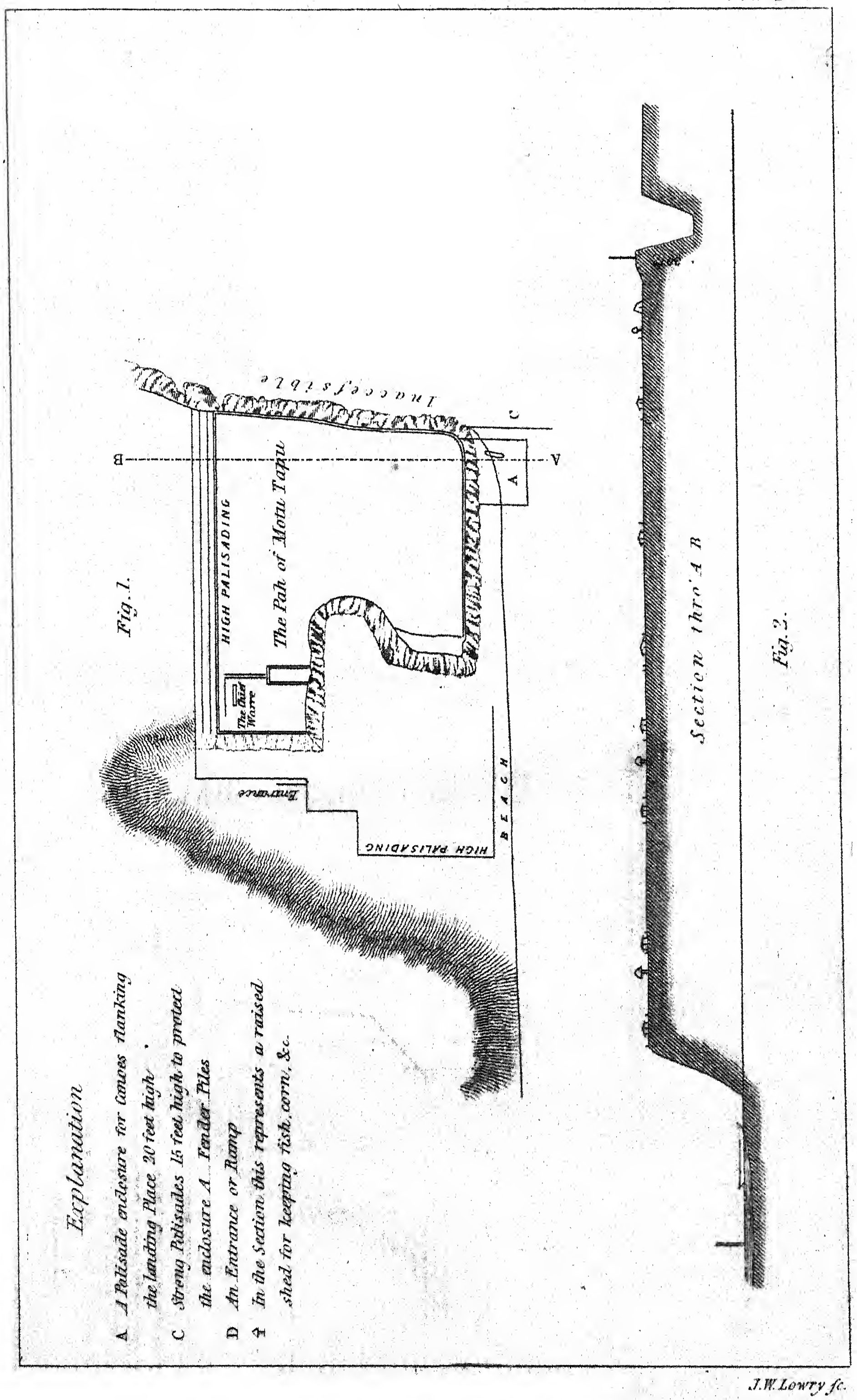
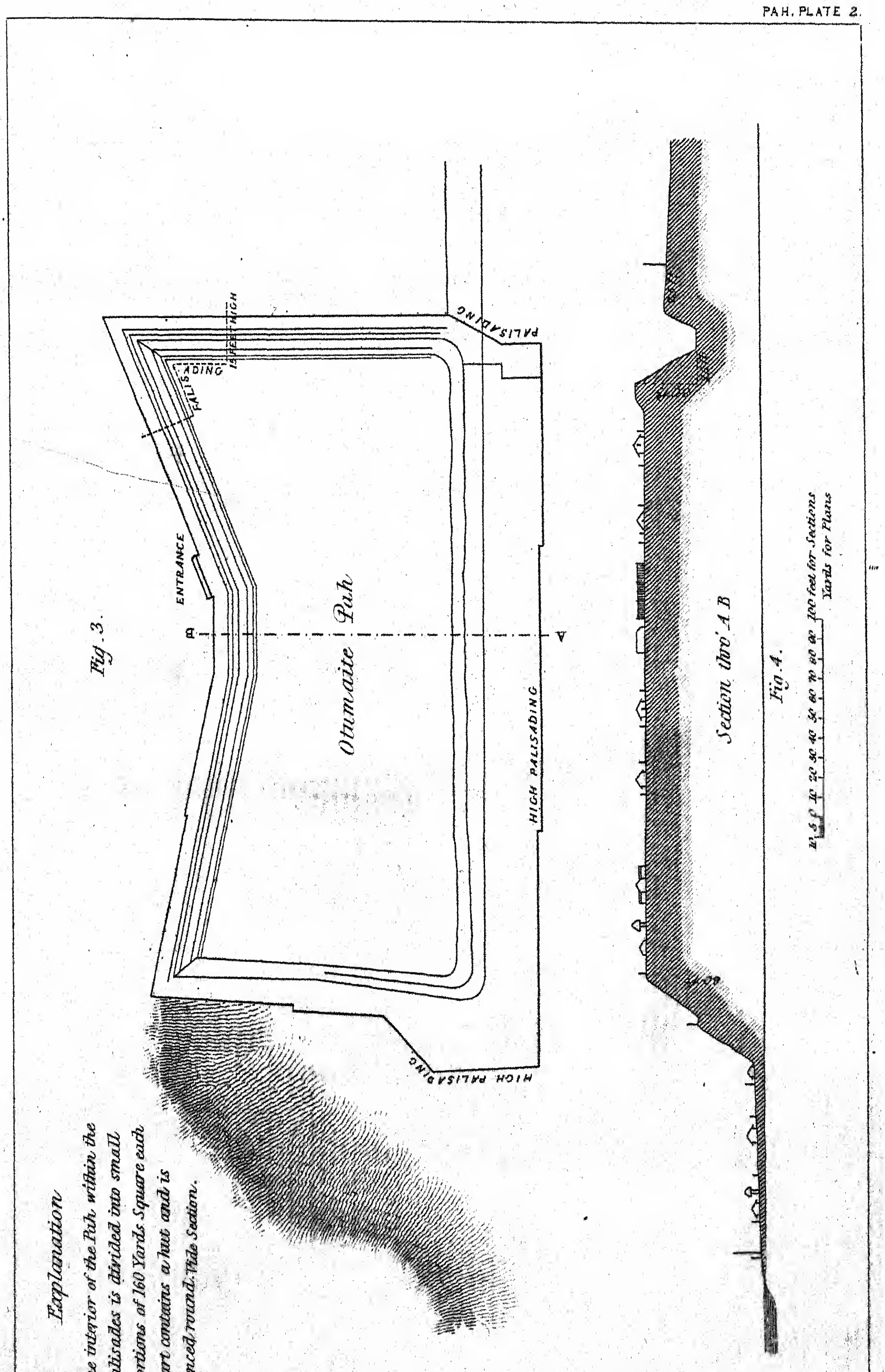


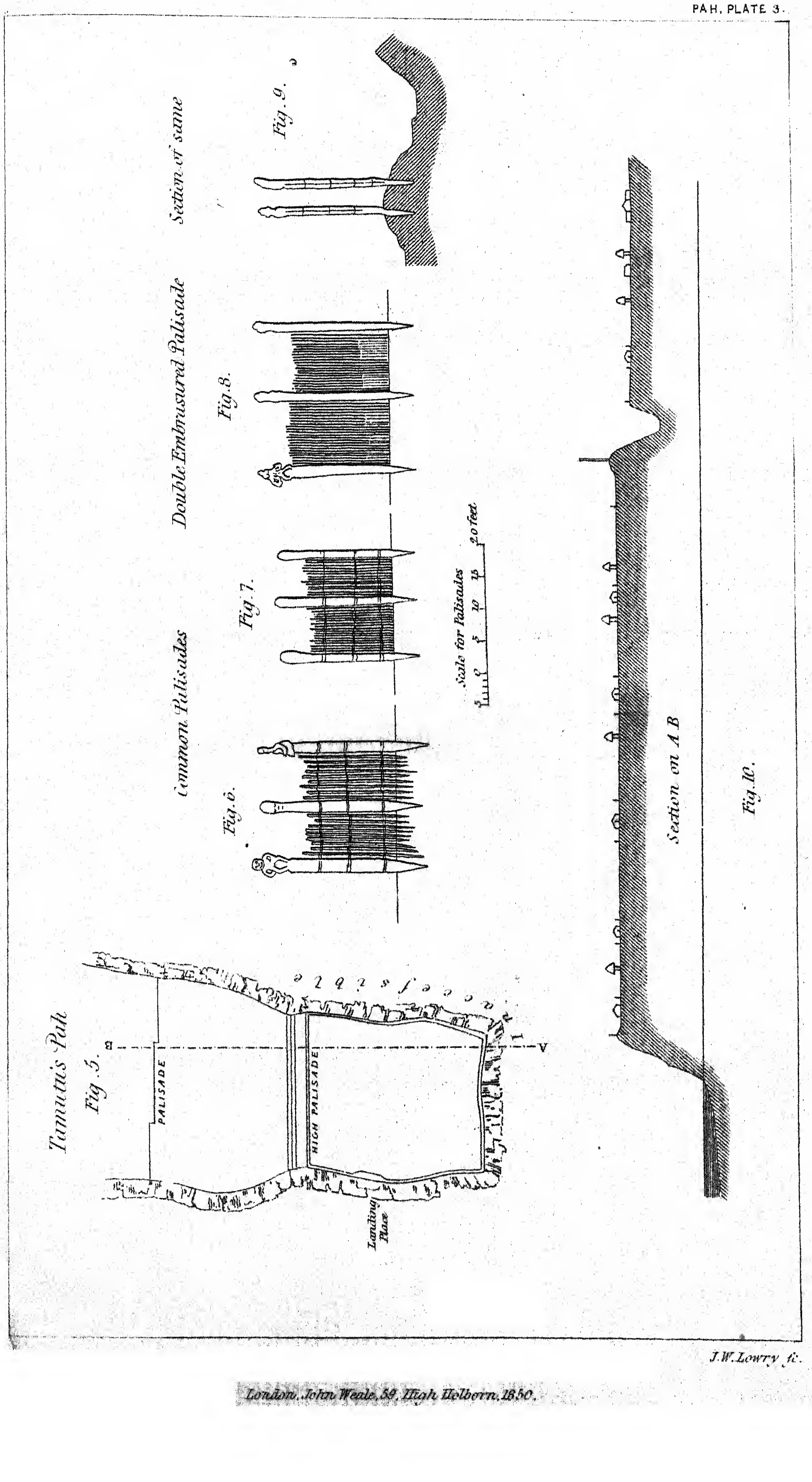
J.W. Lowry fc.

London, John Weale, 59 High Holborn, 1850.



J.W. Lowry fc.

London, John Weale 59 High Holborn 1850.



J. W. Lowry fc.

London, John Weale, 59, High Holborn, 1850.

Plan of Heki's Camp and Pah

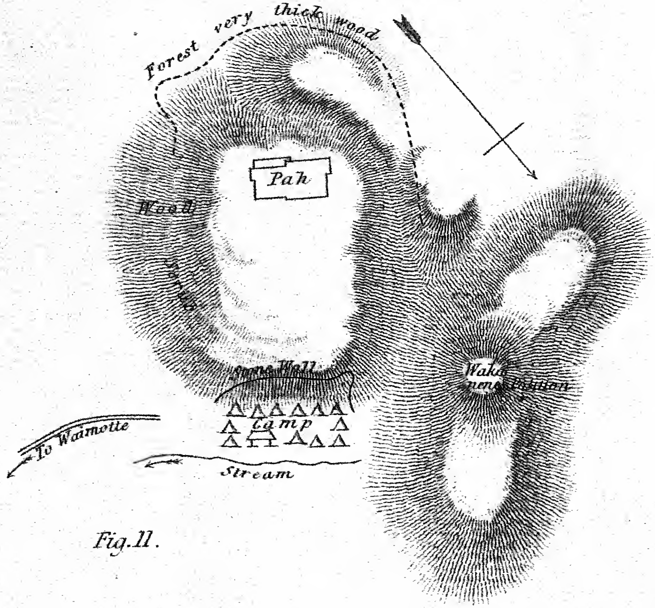
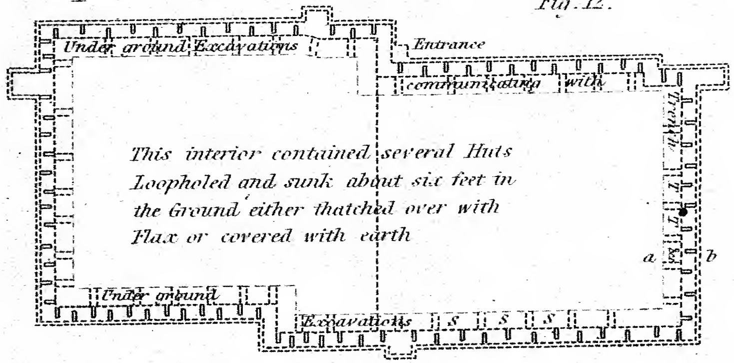


Fig. 11.

Scale of Yards.

100 50 0 100 200 300 400 500 Yards

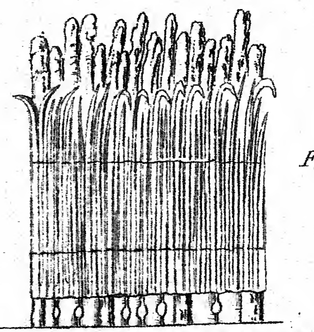
Fig. 12.



Scale to Plan Fig. 12.

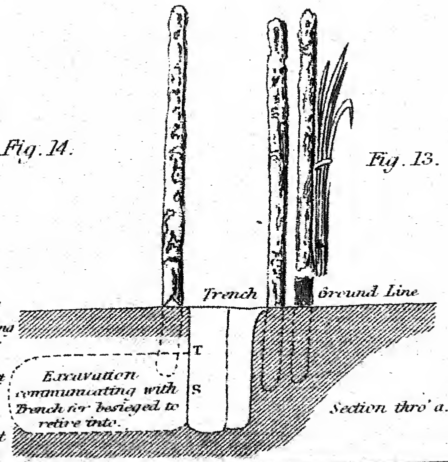
10 5 0 10 20 30 40 50 60 70 80 90 100 200 ft

Fig. 14.



Elevation of Part of the outer Fence of Pah shewing the Flax Screen and Loopholes in the second Fence

Fig. 13.



Section thro' a.b.

Scale to Elevation and Section

0 1 2 3 4 5 6 7 8 9 10 20 feet

J.W. Lowry

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AIDE-MÉMOIRE

TO

THE MILITARY SCIENCES.

FRAMED FROM

CONTRIBUTIONS OF OFFICERS

OF

THE DIFFERENT SERVICES,

AND EDITED BY

COMMITTEE OF THE CORPS OF ROYAL ENGINEERS

1847—1849.

VOL. II.

FORTIFICATION ----- PALANQUE.

WITH NUMEROUS PLATES AND WOOD-CUTS.

London:

JOHN WEALE, HIGH HOLBORN.

M.DCCC.L.

PRINTED BY HUGHES AND ROBINSON,
KING'S HEAD COURT, GOUGH SQUARE.

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